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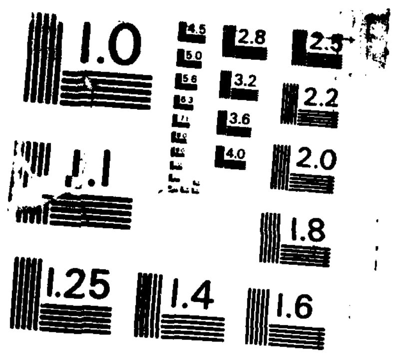


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TECHNICAL REPORT

# ADAPTING DYNA-METRIC TO ASSESS NON-AIRCRAFT SYSTEMS

Michael J. Budde
Captain, USAF

Richard D. Mabe
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AU/AFIT/LSM-86-1





DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

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ABSTRACT: The Air Force uses dynamic programming to assess the wartime logistics of their aircraft systems. However, they do not have a standard methodolcgy to assess the combat capability of non-aircraft systems. This report examines a methodology to apply the Dyna-METRIC model to assess non-aircraft systems. Several systems are discussed: Mobile tactical communications, civil engineering, transportation and space systems. All are assessed in terms of four critical variables: demand rates, sortie equivalents, "fleet" size, and redundancy.

AIR FORCE INSTITUTE OF TECHNOLOGY
SCHOOL OF SYSTEMS AND LOGISTICS

Technical Report:

# ADAPTING DYNA-METRIC TO ASSESS NON-AIRCRAFT SYSTEMS

May 1986

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## Table of Contents

## List of Figures

Figure | Page

## List of Tables

# ADAPTING DYNA-METRIC TO ASSESS NON-AIRCRAFT SYSTEMS

## Chapter I

## Introduction

### Overview

This paper examines the feasibility of applying dynamic programming (specifically the Rand Corporation's Dyna-METRIC model) to analysis of various non-aircraft systems, including diverse command, control and communications ($C^3$) equipment, ballistic missiles, space $C^3$ systems, transportation systems and civil engineering systems. Chapter One outlines the specific problem, objectives and scope of this research effort. Chapter Two begins with a brief introduction to Dyna-METRIC and its dynamic programming concepts. Next, the initial research that applied Dyna-METRIC to non-aircraft systems is discussed. This research by Mabe and Ormston (1984) provided the basis for the research presented in this report. Chapter Three presents the research methodology, results and analysis that go beyond the initial research effort, and evaluates general techniques for applying the model to non-aircraft systems. This portion of the research addresses unanswered questions from past research efforts. Chapter Four discusses potential applications of the model to non-aircraft systems, based on the findings presented in Chapter Three. Chapter Five presents overall conclusions and recommendations on future applications of the Dyna-METRIC model to non-aircraft systems in the Air Force.

## Background

A common picture of the Air Force today is one of sleek fighters at war achieving the Air Force mission -- "to fly and fight." A less visible, but very critical part of this mission is worldwide command, control, and communications provided to operational and support forces. The Air Force has several $C^3$ systems which provide direct support to flying operations. Examples include tactical radar systems, mobile combat communications facilities, air traffic control and navigation facilities, and base communications centers.

Typically these $C^3$ systems consist of multiple end items of equipment, each with its own unique designator (i.e., AN/TPS-43E) and management structure. These end items are grouped into fixed facilities, such as a Base Communications Center, or mobile units, such as a Control and Reporting Post (CRP). Although the majority of the facilities and units belong to Air Force Communications Command (AFCC), other Major Commands (MAJCOMs) own specific systems unique to their mission, such as the air defense radars in the United States and the Tactical Air Control System (TACS) in the Tactical Air Forces (TAF).

Logistics support for these facilities ranges from all Air Force organic maintenance and supply, to all contractor provided maintenance and supply. This support is complicated by the variety of end items, missions, and locations of the $C^3$ facilities and units. Quality logistics support demands computer based Management Information Systems (MIS) and assessment techniques. Yet, the majority of $C^3$ systems supported by the Air Force have

little or no computer based management outside of the Standard Base Supply System and various depot spares management systems.

Supply support provided to any unit or facility is critical to the survival of the facility during peace or war. The Air Force has started to use dynamic programming to analyze possible methods of support for their flying forces, and to help compute wartime supply requirements. Though currently used to analyze support of various types of aircraft (i.e., fighters, bombers, tankers and helicopters), the techniques of dynamic programming have potential for use with non-aircraft systems such as $C^3$ facilities.

## Specific Problem

The Air Force does not have a standard method of assessing the impact of supply support on the warfighting capability of non-aircraft systems. Instead, a variety of manual and computer based methods are used by each MAJCOM and at the wholesale level. Several factors have contributed to not having a standard method. First, a common data base of demand data for parts used on $C^3$ systems does not exist. Further, logisticians at all levels lack an understanding of the relationship between aircraft system operations and non-aircraft system operations. Finally, a clear definition of what each non-aircraft system includes varies with the application of the system. For example, a CRP in TAC and a CRP in USAFE have some differences in equipment and missions.

This lack of a standardized assessment technique causes system managers to develop their own methods. Frequently these

methods have little quantitative backing, and depend more on the experience of system users than on precise quantitative models. As a result, critical wartime support questions go without validated quantitative answers. For example, how much War Reserve Materiel (WRM) is required to keep a satellite tracking, telemetry and command site active during the early days of a war? How many excess spares should a mobile combat control unit carry into battle to provide repair support until "pipelines" to their wartime location can be established? Or, how long can a base communications center operate from its existing shelf stock during a war before it cannot be repaired due to lack of parts?

The Air Force relies on quantitative methods to answer these questions for aircraft systems (such as the WRSK/BLSS Requirements Computation System (D029), or the Sustainability Assessment Module of the Weapons System Management Information System (7; 8)). Yet, they rely more on the experiences of system users and qualitative methods to answer these questions for $C^3$ systems. The Air Force needs a quantitative method to support the qualitative methods currently used to analyze non-aircraft systems. The Dyna-METRIC model can provide the basis for the quantitative method.

## Justification For Current Research

A number of research efforts by AFIT students and faculty have addressed applying Dyna-METRIC to non-aircraft systems. Each study adapted the model to meet specific research objectives rather than to develop generalized approaches which could be

applied to a wide range of non-aircraft systems. For this reason, there are still some unanswered questions about the best method to apply the model in various circumstances. This report addresses these unanswered questions, and documents a valid technique that CE system managers at all levels, and potentially other non-aircraft system managers, can use.

## Scope of Research and Report

The methodology for this research was executed against a data base of supply information on the USAFE TACS provided by the 601 Tactical Control Wing at Sembach Air Base, Germany in 1984. Values for the Dyna-METRIC variables were computed and formatted for use in the model by Mabe and Ormston (1984) for use in their Masters Degree thesis. Their data base is the largest available on a non-aircraft system that is ready for use in Dyna-METRIC. It includes data on a variety of radios, the TPS-43E radar, and EMU-12 power generators.

Specific findings in this paper are based on the TACS data base. However, extensions of the results have been made to similar $C^3$ systems with common end items. Further extensions to civil engineering and vehicle systems were generalized from the results on $C^3$ systems, and were not based on specific results using the TACS data.

## Chapter II

## Literature Review

### Overview

This chapter presents an overview of Dyna-METRIC, addressing background on the development and uses of the model and a brief description of the dynamic programming logic. Next, the research by Mabe and Ormston (1984) on the USAFE Mobile TACS is reviewed. This review includes an analysis of the applicability of Dyna-METRIC assumptions to communications-electronic (CE) systems and a description of their research design and results. An understanding of this initial research effort is important because it provides the basis for discussion in later chapters of this research report.

### The Dyna-METRIC Model

In the last 10 years, researchers at the Rand Corporation have undertaken a series of projects designed to assess aircraft readiness and supportability in a dynamic wartime environment. Steady-state models that were based on peacetime scenarios were found to be inadequate for realistic assessments of dynamic wartime scenarios (11:4). The search for appropriate dynamic models resulted in a series of dynamic queueing equations first used in 1978 by Berman, Lippiat, and Sims (11:iii). These equations, and techniques for their use, were modified and expanded to handle repair and supply capabilities for indentured compo-

nents. The resultant model, which incorporated the features into a usable format, was named Dyna-METRIC. The term "METRIC" was borrowed from Sherbrooke's 1968 model, and stands for Multi-Echelon Technique for Recoverable Item Control. The "Dyna" portion of the name relates to the time dependency aspect of the model in evaluating dynamic scenarios. Hillestad (1982) described the initial model as it was formulated for use in development of the Combat Support Capability Management System (11:iii). The model could be used in two basic modes depending on the desired output; either a capability assessment mode, or a requirements computation mode.

Dyna-METRIC has experienced an evolutionary process, and has been incrementally upgraded through at least a dozen versions released since 1980. Because of its modular design, it has been relatively easy to enhance existing portions and/or add new capabilities to overcome restrictions of earlier versions. The approved version of the model currently used by the Air Force is Version 3.04. This version of the model has been documented and internally validated by the Air Force Logistics Management Center (1; 2) and has been validated against real world exercises by HQ TAC (18). However, the latest series of releases (version 4) provide many significant enhancements not found in the current approved version.

Version 4 models have been released to Air Force (AF) users for evaluation and to conduct research using its new features. Version 4.4, the latest and most sophisticated version, is currently being used by many AF agencies and is undergoing validation and documentation efforts by HQ AFLC/XRS, pending acceptance

by HQ USAF/LEYS to become the AF standard version. Because of the significant improvements provided by version 4 models, most research efforts in the past two to three years have used these versions. Similarly, the research reviewed and conducted in this report is all based on version 4 models.

Although the various versions provide different features and additional capabilities, the basic logic and processes are common to most of the versions. The following review of the Dyna-METRIC model primarily addresses the basic common logic. Dyna-METRIC views an airplane as a collection of spare parts waiting to fail. Failures require replacement, and if replacements are not available, the aircraft is determined by the model to be Not Fully Mission Capable (NFMC) for supply reasons. Dyna-METRIC considers spare parts to be available from stock, from the maintenance process, or from cannibalization. In order to determine the availability of assets from maintenance or higher echelons of supply, the model computes the number of assets tied up in transportation and maintenance pipelines.

The model's treatment of facilities and associated pipelines can be described by a general scenario where two or more bases with identical Mission Design Series (MDS) aircraft are tied by resupply lines to support depots (Figure 1). The in-house repair capability at each base may be augmented by a Centralized Intermediate Repair Facility (CIRF) which, in-turn, is supported by the same depot as the bases. Each location has unique repair capabilities (repair cycle times, NRTS rates and condemnation rates) for different types of parts (remove and replace (RR);

remove, repair and replace (RRR); SRU; and engine), unique resupply availability, and unique transportation times between facilities. Each location can be selectively supported by an industrial source of supply to replace condemned assets.

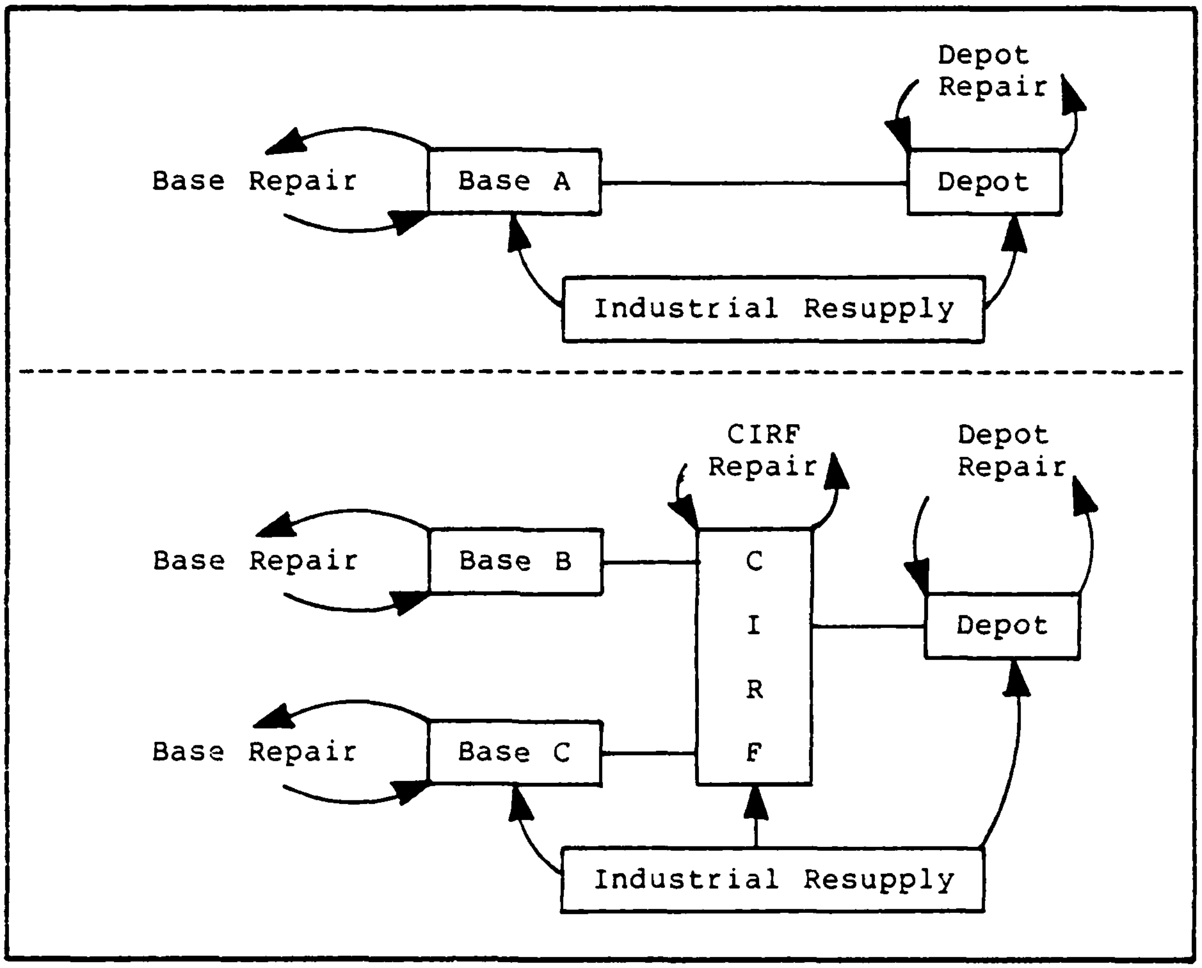


Figure 1. Dyna-METRIC View of Pipelines

The model uses a derivation of Palm's Theorem (16) to compute the values for the pipelines shown in Figure 1. Hillestad and Carrillo (1980) explained a modification to Palm's Theorem which accounted for the time dependency of items in a queue. This modified theorem is based on a non-homogeneous

Poisson distribution that accounts for non-stationary demands and service times (Figure 2).

In the mathematics of the model, a set of analytical equations is used to describe the dynamic behavior of the component repair queueing system. The equations center primarily on a demand function M(s), and a service distribution F(s,t) (11:9).

Service Function: $F(s,t) = P$ (a component entering repair at time s is still in repair at time t)

Demand Function: $M(s)$ = (failures/flying hour) X
(flying hours/sortie at t) X
(# of sorties/aircraft at t) X
(# of aircraft at t) X
(quantity per aircraft) X
(% of aircraft with the part)

Then, the expected pipeline quantity, L, is:

$$L(t) = \int_{0}^{t} F(s,t)\, M(s)\, ds$$

And, the probability of having k components in repair at time t is:

$$P(k) = \frac{L(t)^{k}\, e^{-L(t)}}{k!}$$ (non-homogeneous compound Poisson distribution)

Figure 2. Extension of Palm's Theorem

Other variables are used to describe resupply pipelines and provide limits on the service distribution, including order and shipping times, transportation times, NRTS rates, and repair cycle times.

By using the modified theorem, the model captures dynamic demands and transient behavior generally associated with variable flying hours and sortie surges. The daily values add a dimension of time to the model not found in earlier steady-state METRIC and base stockage models (12:Sec II).

Once the mean pipeline quantities for each part are computed for a given day, then the model checks on the stock available and converts this pipeline distribution into a backorder distribution to derive the expected number of backorders for each part. With the computed backorders for all parts, the model considers the quantity per aircraft for each part and the effect of cannibalization policies to compute the expected number of NFMC aircraft. Since the model does not consider Partially Mission Capable (PMC) aircraft, those aircraft not grounded are assumed to be Fully Mission Capable (FMC) and thus, available to fly sorties that day. The number of FMC aircraft together with the user specified maximum sorties per aircraft variable, are used to compute the expected number of sorties for that day.

In addition to predicting the performance of aircraft units, Dyna-METRIC also identifies potential problem items which prevent the units from meeting their specified level of performance. The user must specify an acceptable level of degraded aircraft (NFMC target) and a desired level of confidence for achieving that NFMC target. The model compares the expected number of NFMC aircraft on a given day to the acceptable level and computes the probability of meeting the goal. When the computed probability drops below the user specified confidence level, then a rank ordered

list of problem parts is generated. Only those parts which prevent the unit from achieving the specified NFMC target with the desired level of confidence are listed.

Dyna-METRIC also has the capability to compute the level of stock for each item needed to meet the target NFMC goal. After computing the mean pipelines, backorders and expected NFMC aircraft (as already discussed), the model determines the level of stock required on each day to meet the desired NFMC target and confidence, and lists these levels as recommended stock levels.

The ability of Dyna-METRIC to forecast operational measures of combat capability based upon given levels of logistics resources, and to identify potential performance limiting assets, makes it an invaluable tool for Air Force management. The output measures allow the user to focus time and resources on assets that will provide the greatest return in terms of combat capability.

Although designed and originally used to evaluate logistics support of tactical flying units, a number of research efforts have demonstrated the flexibility inherent in the Dyna-METRIC model. This flexibility has enabled it to be adapted to resource groups other than recoverable spares (3; 15), to non-tactical aircraft systems (8; 9; 19) and even to non-aircraft weapon systems (14).

Research on USAFE Mobile TACS

In September 1984, Captains Richard D. Mabe and Robert E. Ormston completed their AFIT thesis research where they used the

Dyna-METRIC model to evaluate the mobile Tactical Air Control System (TACS) in Germany. They were the first to demonstrate that Dyna-METRIC could be applied to non-aircraft weapon systems. They modeled each of 15 radar units at a separate base, where each unit was composed of a primary radar set, radio vans, and mobile power generators. Each of the bases/units were supported by intermediate and depot level supply stocks. Mabe and Ormston made no changes to the model logic, but did have to redefine some of the model input variables and interpret the results in terms related to CE systems. Their research effort will be carefully reviewed in the remaining portions of this chapter. The research on the TACS system forms the basis for the follow-on research presented in this paper; therefore, it is important for the reader to understand the nature and results of Mabe and Ormston's research.

Applicability of Dyna-METRIC Assumptions to CE. When Dyna-METRIC is used to assess the capability of aircraft systems, many of the modeled components are avionics, or electronic components. The nature of operation and failure for these components should be essentially the same, whether the components operate from an airborne platform or from a ground-based platform. Therefore, to the extent that model assumptions are appropriate for avionics components, they should be equally applicable to ground-based components with similar functions. Mabe and Ormston conducted a careful review of the Dyna-METRIC assumptions and logic to determine if the model could be used to analyze non-aircraft systems.

Seven key assumptions, drawn from Hillestad's 1982 description of the model, had the most potential for affecting the application to CE systems. These assumptions, and their possible impact on modeling CE systems, are discussed in the following paragraphs.

1. Component failures are time dependent, and directly proportional to the flying program and fleet size of any given base (11:47). Pyles states this assumption was made because no one has developed a mathematical technique to express component failure in terms of other variables; however, the subject is under continuing research (17:34). Workarounds are available that allow the user to adjust the demand rate to trick the model into generating an appropriate level of demands based on number of sorties, rounds fired or operating hours (18). Once this adjusted demand rate is entered; however, the number of generated demands remains a function of the flying program. In general, the number of demands generated should increase as the number of operating hours (equivalent to flying hours) increase. Even the possible increase in failures that may be caused by frequent power up and power down cycles can be captured in a computed demand rate, and thus be modeled in Dyna-METRIC. This assumption seems logical and reasonable for CE systems.

2. The repair and failure processes are independent (11:11). This assumption was made for simplification of the mathematics. Intuition suggests that the failure rate does influence the repair rate, and perhaps the quality of repair, when there are large quantities of parts to repair with only a short time to repair them. In other words, the model assumes

maintenance cannot adjust its rate of repair to reduce the time it takes to repair each item. Therefore, the result of this assumption will more than likely be an overstatement of system capability and availability of spare parts during periods of highly demand generation. This assumption should be equally applicable to aircraft and CE systems.

3. The number of failures occurring in any given time period is independent of the number occurring in a similar period, but centered on a different time (11:11). According to Pyles, this assumption was made as an attempt to hold down the amount of data needed to run the model (17:37). For non-aircraft systems this is probably as good of an assumption as it is for aircraft components, and no negative impact is expected.

4. The component failure distribution is the result of a non-homogeneous compound Poisson process described earlier. Because most of the systems studied in this research were electrical, then this assumption should hold true. Hillestad and Carrillo's modification of Palm's Theorem adds quite a bit of flexibility to the failure process. Pyles states the Poisson distribution is "robust," which means that one needs to deviate from the assumptions of the repair and failure processes substantially before exceeding the bounds of the Poisson distribution (17:27). For Components where the Mean-Time-Between-Failures (MTBF) does differ substantially from the exponential requirement of the Poisson, the model can be made to portray a binomial or a negative binomial failure distribution. These distributions can be used to represent spacing or clustering of failures respectively.

5. Cannibalization actions are instantaneous, and holes in the aircraft are minimized and consolidated to the smallest number of airframes. Hillestad says this cannibalization would only occur when needed, and the result of this assumption would likely be an overstatement of capability (11:30). Cannibalization was not evaluated during this research, because each radar unit was modeled as a single "aircraft" on a base and there was no similar units to cannibalize from. Since many CE systems are composed of several end items, it is possible to cannibalize from one piece of equipment to another, but Dyna-METRIC cannot represent this internal cannibalization. This imitation may understate capability for CE systems if a particular system has the structure that would allow extensive internal cannibalization.

6. Sub-components and their parent assemblies fail independently. Hillestad concludes this assumption also over-states capability, and causes over cannibalization of the sub-components. He goes on to say though, that the assumption does lead to reasonable approximations since the rate of each sub-component failure is considerably smaller than the parent failure rates (11:46). There should be no real difference between air-craft and CE systems regarding indentured components.

7. Sufficient slack service capacity exists to avoid queueing in the repair of components. Hillestad reports this assumption to be valid as long as average demands remain less than 80% of the service capacity (11:77). Obviously this does not hold true for surges in flying activity. When modeling

surges, users should use the test equipment feature of Dyna-METRIC, where the user identifies the number of "work stations" available for maintenance. These stations can be test stands, personnel, work centers, or anything describing the limitations on how many parts can be repaired at one time. The model then uses a simulation process to analyze the service capacity and failures, and assigns repair to the work stations based on a priority system. In the stock requirements mode, an analytical subroutine computes higher stock levels that need to be achieved to meet the surge demands. This assumption applies equally to aircraft and CE systems.

This analysis revealed that there was nothing in the assumptions of the model that would make the model invalid for use with non-aircraft systems. Similarly, the model had sufficient flexibility to model the most important elements of the TACS structure in a wartime environment. However, some of the input variables needed to be defined or treated as a CE equivalent to the aircraft variables used in the model. Finally, the output results had to be interpreted relative to CE systems and appropriate to the model structure used. The next sections describe these adjustments that were made by Mabe and Ormston to model the TACS in Germany.

Structural Model. The objective of Mabe and Ormston's thesis research was to demonstrate that forward supply points between Sembach AB and the 15 geographically separated TACS units deployed throughout Germany would improve the supply support and

capability of the units. To accomplish this they did a comparison of the current structure of the TACS support system (one set of Dyna-METRIC runs) with a proposed supply structure that included intermediate supply locations (a second set of Dyna-METRIC runs). Mabe and Ormston divided Germany into a northern and southern region, with each region having a forward supply location. Separate runs were made for each region. The following discussion describes the structure of one region only, since both are very similar. A complete listing of the Dyna-METRIC data file for the northern region is included in Appendix B.

The support provided to the TACS units consisted of: 1) the WRSK assets authorized for each end item making up each operational unit, 2) resupply from Sembach and an intermediate resupply point and 3) maintenance capability organic to each deployed unit. Sembach and the intermediate supply points were modeled as a depot and CIRFs respectively, each with stocked assets only and no maintenance capability (see Figure 3).

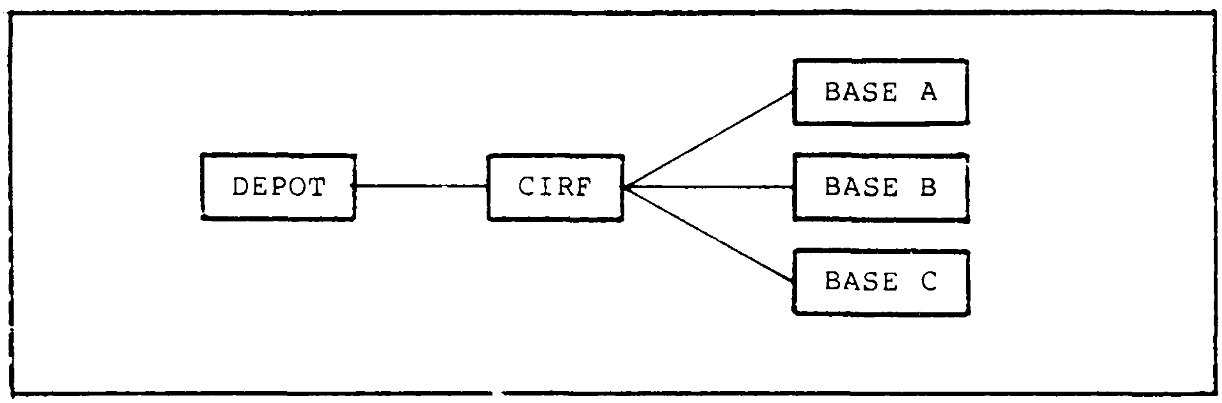


Figure 3. TACS Scenario Structure

Two basic types of units were evaluated, Control and Reporting Posts (CRP) and Forward Air Control Posts (FACP). The

individual pieces of equipment that make up each unit are shown in Figure 4. Each unit was treated as a single "aircraft" composed of the equipment shown, and each base had only one "aircraft" assigned to it. All of the WRSK spare parts that were authorized for each piece of equipment were aggregated into a single data file, thereby representing the total assets available to support the composite CRP or FACP. The application fraction feature of Dyna-METRIC was used to indicate which parts were applicable to the appropriate unit assigned to each base (whether a CRP or FACP).

| | | |
|---|---|---|
| CRP Equipment: | TPS-43E Radar | TRC-97A SHF Radio |
| | TRC-87 UHF Radio | TGC-28 Secure Teletype |
| | TSC-60 HF Radio | EMU-30 Generator |
| FACP Equipment: | TPS-43E Radar | TRC-97A SHF Radio |
| | TSC-53 UHF/HF Radio and Secure Teletype | EMU-30 Generator |

Figure 4. TACS Unit Equipment

<u>CE Variable Definitions</u>. Given that Dyna-METRIC assumptions are appropriate for CE equipment and the support structure could adequately be modeled, all that remained was to assign values to the remainder of the input variables required to model the TACS operation. As mentioned earlier, several input variables are unique to aircraft systems, and in order for the model to work for CE systems, these variables would have to have a parallel definition for CE equipment. Mabe and Ormston identified three

key variables that needed to be redefined for CE systems. These three variables were: demands per flying hour, sorties and the operational unit or fleet size. One other variable that was identified as being critical to the analysis was the Quantity Per Aircraft. Although QPA is the same for aircraft and CE systems, it is especially critical for determining NFMC units for systems that have a lot of redundancy. Figure 5 shows the general structure and relationship of the four key variables redefined in their research.

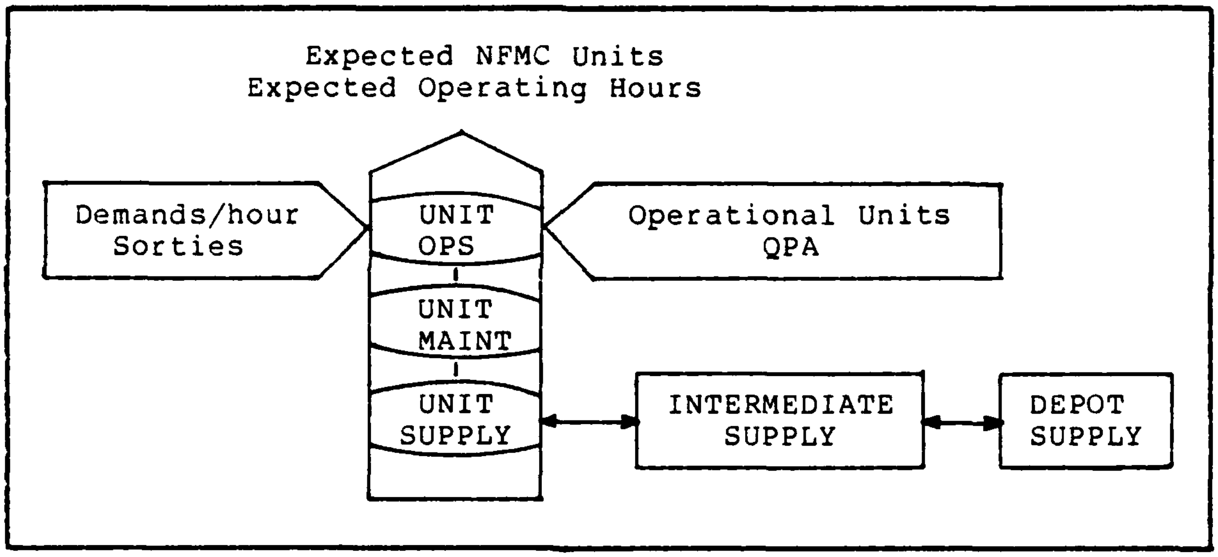


Figure 5. CE Variable Relationships

Mabe and Ormston were able to develop appropriate definitions/uses for each of these critical variables. Essentially, they defined "demands per flying hour" to be demands per **operating** hour, and computed the value based on the demand for each individual part across all 15 units over a 15 month period. They defined an aircraft "sortie" for radar units to be an operating cycle whose duration was specified by the sortie duration

variable. In this way the product of the number of operating cycles and the operating cycle duration yielded the total number of hours the unit was required to operate that day. This resultant value multiplied by the demands per operating hour determined the number of failures each day, a direct parallel to the demands generated by the total number of flying hours requested each day for aircraft units.

An operational unit for aircraft weapon system is typically a squadron composed of multiple aircraft of a semi-homogeneous type or MD (all F-16s, F-4s or F-15s). Dyna-METRIC allows only one type of aircraft (MD) to be modeled at a single base. For the TACS, the operational unit is a single mobile radar unit composed of many separate MDSs. Therefore, Mabe and Ormston considered the multiple end items in each unit to be one aircraft, making a fleet size of one at each base modeled (14:ch4).

Many CE systems have a lot of redundant capability built in, which allows the unit to provide some level of capability despite component failures. In Dyna-METRIC, the minimum QPA determines the number of components which can fail before causing a NFMC unit. Mabe and Ormston input a minimum QPA value for each end item. The values they used were based upon the minimum number of end items NATO required to be operational for a unit to be considered PMC. However, Mabe and Ormston did not extensively evaluate the sensitivity of the model to changes in this new version 4 feature.

The particular CE system modeled for this research was the Tactical Air Control System in Germany, a mobile radar and communications system designed to detect enemy aircraft entering NATO airspace. From a modeling point of view, this probably represents the most difficult scenario that would need to be evaluated. To the extent it can be demonstrated that Dyna-METRIC can adequately model a mobile scenario, the application of the model to fixed systems should be straight forward as described thus far in this report.

The mobile TACS operates in a very dynamic environment, where a unit operates from a location for a few days, shuts down and moves to a new location to set up operation. This subsequent location is a different distance from its in-theater source(s) of supply. During the time the unit is deploying to a new location, the user can specify that no operating hours are required and, therefore, no demands will be generated during that time. The difficult part to model is the varying distances from the unit to its support facility (depot or CIRF), since Dyna-METRIC only allows a single input to represent these distances within a single model run. In order to change the transportation distances, several separate runs must be made, each with a different time. However, these separate runs must be linked to create a continuous run where the pipeline quantities from the end of one run become the starting pipeline quantities for the next run. Dyna-METRIC options 10 and 16 allow the user to do just that.

Mabe and Ormston originally attempted to tie separate files together, while varying transportation times between locations in between runs. Their approach was to make three separate runs where the first would look at the first 9 days of analysis, the second would evaluate days 10 through 18 and the third would evaluate days 19 through 27. Within each run, selected units would be moved (taking 3 days) at the end of the evaluation period, so that when it started up in the next run, a new transportation time could be specified in the subsequent data file.

The input files were run sequentially where option 16 was specified in each to save the pipeline status at the end of the run. After transportation times were changed, option 10 was included in the file so that the subsequent run started with the ending pipeline status of the previous run. Mabe and Ormston encountered erroneous results in using Options 10 and 16; the number of assets in several of the pipelines decreased significantly from the end of one run to the beginning of the subsequent run. Because of time constraints, Mabe and Ormston could not wait for the problem to be resolved, and were forced to modify their methodology and complete their research without evaluating the effect that varying pipelines would have on unit capability.

Interpretation of Output. Just as aircraft unique inputs needed to be defined in terms of CE systems, some of the outputs generated by the model required similar interpretation in terms of CE systems. Figure 6 displays a portion of the overall unit performance report that is generated for each day of analysis.

Since the most significant interpretation of output for CE systems relate to this report, they will be briefly reviewed below. As a basis for discussion, Figure 6 shows a sample output for one base from the northern region.

Dyna-METRIC primarily reports performance at each base in terms of NFMC aircraft and the number of sorties that can be flown with FMC aircraft, along with other related and supporting data used to determine these outputs. Since sortie input variables were redefined in terms of operating cycles, the corresponding sortie related outputs can be interpreted in the same terms.

PERFORMANCE BASED ON STOCK ON HAND ON DAY XX

| | | ---------FULL CANNIBALIZATION---------- | | | | | |
|---|---|---|---|---|---|---|---|
| BASE | TARG NFMC | PROB 0% NFMC | PROB ACHIEVE SORTIES | FMC 80.% CONF | E(NFMC) | E(SORTIES) | TOTAL BACK ORDERS |
| 606C | 0 | 0.499 | 0.499 | 0 | 0.501 | 11.97 | 7.11 |

Figure 6. Sample TACS Output

The sample output shows that the base can fly 11.97 sorties, which in terms of CE systems, indicates the radar unit can perform 11.97 operating cycles of 1 hour each (i.e., it is expected to operate 11.97 of the 24 hours requested in the scenario). All other sortie reported outputs can be interpreted in a similar manner.

Special interpretation is also required for all outputs reported in terms of aircraft units. Mabe and Ormston specified that 0% of the units were desired to be NFMC (since there is only one) 80% of the time (confidence level). Dyna-METRIC computes the expected number of NFMC units "E(NFMC)" and compares this to the "TARGET NFMC" level (0% multiplied by the number of units) and then computes the "PROB(ability) 0% NFMC," which is the probability of meeting the required level of capability. Remember that there is only one unit per base, therefore, the expected number of NMCS units has to be one or less.

The sample output in Figure 6 shows an E(NMCS) of .501, which indicates that half of the unit is NFMC. Discussions with Ray Pyles at RAND led to the conclusion that the model should be mathematically accurate for small aircraft fleet sizes and that a more appropriate way of interpreting output for single unit bases is to expect the single unit to be NFMC about fifty percent (.501) of the time. It is interesting to note that the probability of having 0% NFMC units and the E(NFMC) units always add to 1 with a single unit.

Most other outputs of the model deal with identification of problem items and item specific values representing pipeline quantities and backorders which are interim values used to compute overall unit level performance. Most of these outputs can be interpreted the same for aircraft and non-aircraft systems. Mabe and Ormston did some additional analysis based on the problem parts listing to try to determine a Partially Mission Capable

Status. As long as the number of "holes" for a part in each end item does not exceed the minimum QPA for the item, the model reports the unit as FMC. In the real world, however, it could actually be PMC. Therefore, Mabe and Ormston evaluated the items listed in the problem parts listing, compared the shortages to the minimum equipment required by NATO for mission capability, and made an external classification of units as PMC versus FMC. NMC units reported by Dyna-METRIC were accepted as actually being non mission capable.

Mabe and Ormston reported that their results applied to mobile communications-electronics units, and might also apply to static units using the same logic and interpretation of variables they used. However, they did not actually evaluate static $C^3$ facilities such as base communication centers, ground tracking stations, or launch control facilities.

Validation. Mabe and Ormston's research results indicate that the model can be directly applied to CE equipment and produce reasonable results. This conclusion, however, is somewhat subjective, although it is supported by personnel knowledgeable of the model's functions and capabilities. In order to more objectively validate their approach to modeling CE equipment, Mabe and Ormstom correlated Dyna-METRIC results with real world exercise experiences. This was done at an early stage of their research to test the feasibility of their proposal. The validation aspect of their research was accomplished using version 3.04. In this way, it also served as a basis to confirm

that version 4 would give the same results as its predecessor (using comparable features in both).

Mabe and Ormston obtained pertinent TACS data collected during the REFORGER 1983 exercise. They used this data to built a Dyna-METRIC data file with a scenario depicting the activity that occurred during REFORGER. The results from the model using this empirical data closely matched the actual operational posture of the four radar units during the exercise. Because the results matched real life, they felt their interpretation of the variables was accurate, and would lead to reasonable output from the model for mobile radar systems. Based on the success of this effort, they then switched to version 4, re-built the TACS data files and made several runs of the model to evaluate the feasibility of using forward supply locations to support the radar units (the research described earlier in this chapter). Each run produced reasonable results, and further supported the ability of Dyna-METRIC to evaluate non-aircraft systems (14: ch4).

The nature of AFIT thesis research, as well as the time allowed, dictated that Mabe and Ormston carefully define a specific problem of reasonable scope. For this reason, they used the model to support their research objectives, rather than a more general study that would have evaluated alternatives and developed generic approaches that may apply to a wide range of non-aircraft systems. Therefore, upon completion of their research, several areas still required further attention.

Specifically, there were several questions that needed to be answered before broader generalizations could possibly be made to non-aircraft systems beyond the TACS, and even beyond CE systems. These questions are as follows:

1. Was there a better method of computing demands per operating hour for CE equipment?

2. Was there a better way to define sorties that could make interpretation of outputs easier (a different ratio of sorties to operating hours, perhaps)?

3. Was modeling each unit as a single aircraft composed of multiple end items the best way to account for having only a single MDS capability?

4. How important is the minimum QPA in determining capability (i.e., how sensitive is model output to changes in the minimum QPA variable)?

In addition to these questions, Mabe and Ormston were not able to completely evaluate Dyna-METRIC's ability to model the mobility of the TACS. They were not able to execute their original experimental design because of problems with options 10 and 16 (these options allow one Dyna-METRIC run to start with ending pipeline status of a previous run). Without these options, they could not vary the distances between units and resupply points when the unit moved from one location to another. This research report is designed to specifically address these unanswered questions and to attempt to develop some generalized approaches to apply Dyna-METRIC to a wide variety of non-aircraft systems.

Summary

Dyna-METRIC is an analytical model that uses the Poisson Distribution to describe parts failures, and a modified Palm's Theorem to compute parts in a given pipeline at specific points in time. The model then uses these computed pipelines, and available stock at a given location, to compute the expected backorders for stock at that location. The holes caused by the backorders are spread across the fleet according to the cannibalization policy being used (i.e., full-cann, or partial-cann) to determine the number of available aircraft. Next, the expected number of sorties the fleet can fly is computed based on this expected number of available aircraft. Despite its obvious aircraft orientation, Dyna-METRIC has a lot of inherent flexibility, and the underlying logic should be applicable to non-aircraft systems with similar components and support concepts. Mabe and Ormston were the first to demonstrate this capability when they modeled the mobile Tactical Aircraft Control System in Germany.

Mabe and Ormston concluded the application of the Dyna-METRIC model to any system requires a minimum of two basic elements: 1) a definable operating cycle for the system, and 2) demand data that is, or can be, related to the operating cycles. For aircraft systems, the typical operating cycle is a sortie. However, for $C^3$ systems, the concept of an operating cycle becomes abstract and hard to define. System users do not speak of

their operations in terms of operating cycles, and do not track and store data that can be related to an operating cycle such as the aircraft sortie. However, operating cycles can be inferred, such as hours of operation in a day, but relating them to demand data stored by base supply becomes tedious and subjective. Given that the demand data and an operating cycle can be somehow related, the next thing to do is evaluate the system against the assumptions of the model and determine if the data will "fit" the algorithms specified in the logic.

The key to applying the model seemed to be in defining the variables in terms of the system to be modeled. Mabe and Ormston's research project addressed how to define the Dyna-METRIC variables in terms of communications-electronics systems. Their research generated the specific questions that were evaluated and answered by the research presented in the remainder of this report.

## Chapter III

## Applying Dyna-METRIC to Non-aircraft Systems

### Overview

The objective of this paper is to propose a method to apply the Dyna-METRIC model as an analysis tool for non-aircraft systems. Mabe and Ormston found that the keys to using the model for non-aircraft systems were collecting and formatting appropriate data and defining Dyna-METRIC input variables and output measures in terms of the system being evaluated. Therefore, the focus of the research presented in this paper is to test and evaluate alternative ways of defining variables in an effort to recommend general techniques that should be applicable to a wide range of non-aircraft systems.

This research was conducted using an updated version of the data base from Mabe and Ormston's research. The Air Force does not now have a method to store and track demand data for their $C^3$ systems that can be tapped for use by the Dyna-METRIC model. To save time, the data base on the radar units was used because it was already formatted for use in Dyna-METRIC, and had provided reasonable results when used in the model. The TACS radar system was a good representative $C^3$ system, and their data base included a variety of radio, radar, and power generating systems.

This portion of the report is divided into five subsections, one for each of the variables, and a fifth which demonstrates the ability of Dyna-METRIC to model mobile CE systems. Each subsection begins with a brief background about the variable and a

discussion of its significance in relation to model computations. The experimental design used to evaluate the variable is then described, followed by presentation of the research results and an analysis of those results.

## Critical Variable Adjustments

Mabe and Ormston identified four significant variables that affected the application of Dyna-METRIC to CE systems: the demand rate, sorties, operational unit (aircraft) and quantity per application. They defined these variables to achieve their specific research objectives, which did not include an exploration of alternative definitions that might be needed for other non-aircraft systems. This section describes follow-on research intended to conduct this exploration.

The basic research approach was to first develop a baseline Dyna-METRIC run based on the mobile TACS scenario described earlier. For each of the four variables, various alternative definitions were developed. Additional Dyna-METRIC runs were made, changing only one variable/alternative at a time. Each of the additional runs were compared to the baseline in terms of accuracy, differences, and interpretability for non-aircraft systems. This approach enabled the authors to explore alternative methods of defining Dyna-METRIC variables in order to determine which method produced the most meaningful results for non-aircraft systems.

Demand Rate. In their thesis research, Mabe and Ormston used a straight-forward demand computation where actual demands

were divided by the number of operating hours (multiplied by the QPA) to arrive at a demand per operating hour to enter into Dyna-METRIC.

$$\text{DEMAND/OPERATING HR} = \frac{\text{TOTAL DEMANDS}}{\text{TOTAL OPS HRS * QPA}}$$

This procedure assumed that all failures came from one distribution and were considered "on-time" failures; that is, all failures that occurred were assumed to occur while the equipment was powered up and operating. This procedure further assumed that failures occurred at a constant rate, and were independent of any previous failures. This implies a Poisson failure rate, with associated exponential Mean Time Between Failures (MTBF).

The nature of CE systems is one where equipment failures can only be detected when the equipment is powered on and operating. However, it is possible that components can break when the system is powered down; that is through handling and transport, or at the instant the system is powered up or down. A distinction between failures that occur while the system is up and running versus those caused by power surges and physical handling can be important to making decisions about the number of spare parts to buy to support CE systems. As such, AFLC/MMMR feels that the distinction between on-time failures and off-time failures should be evaluated.

AFLC/MMMR feels that a single distribution approach may not sufficiently represent the demand generation process for CE equipment. They are working to develop a dual distribution approach where an on-time distribution is computed independently

from an off-time distribution. A WRSK requirement would be a function of both distributions, so demand rates for spares analysis using Dyna-METRIC should also be a function of both distributions.

Capt Mabe assessed AFLC's initial approach and found it to be inadequate. Formulas used in the initial MMMR method are displayed in Figure 7. This report compares the method developed by AFLC/MMMR with Mabe and Ormston's approach in an effort to determine the strengths and weaknesses of each, and to recommend an approach which is both appropriate and adequate to meet the needs of the CE community.

$$\text{ONT HRS} = \frac{(\text{OPS HRS/DAY})*(\#\ \text{UNITS})}{24*(\#\ \text{UNITS})}$$

$$\text{DATA MONTHS} = (\#\ \text{MONTHS})*(\#\ \text{UNITS})$$

$$\text{ONT FAILURES} = \frac{\#\ \text{OPERATING FAILURES}}{(\text{ONT HRS})*(72)*(\text{DATA MONTHS})}$$

$$\text{OFFT FAILURES} = \frac{\#\ \text{NON-OPERATING FAILURES}}{(1 - \text{ONT HRS})*(72)*(\text{DATA MONTHS})}$$

Figure 7. AFLC Demand Rate Formulas

Both methods were evaluated using a common set of inputs so that differences in the results could be attributed to the different methodologies. The number of operational hours was derived assuming an average of 12 (of 15) TACS units operated each day, and that each unit operated an average 8 hours each day. The length of the period that was evaluated was 18 months. Each TACS unit was treated as a single aircraft on a base (with the

number of authorized units equal to 1). The comparison was based on 12 national stock numbers (NSN) authorized for the TPS-43E WRSK used at each TACS unit. Each part had a QPA equal to one. All demand data for these items over an 18 month period came from item record information stored in the U-1050 II computer at Sembach AB base supply. Information from Sembach was in the form of an R-29 Problem Item List for the TACS WRSK. The information was obtained from Sembach, because it is the only base supply account used by all 15 TACS units, and as such, the units and base supply form a closed system, and the data evaluated applied strictly to the units evaluated in this research.

The AFLC approach requires that data be collected on the number of on-time failures and the number of off-time failures (the critical variable in their technique). Since this data was not available, the sensitivity of the resultant demand rate to changes in the ratio of on-time to off-time failures was evalated. Specifically, the ratio of on-time failures to off-time failures was varied in eight increments from 0% on-time and 100% off-time failures to 100% on-time and 0% off-time failures. The on-time demand rate was added to the off-time demand rate, and this total demand rate was compared to the standard demand rate computed by Mabe and Ormston's approach. The demand rates for all 12 NSNs were calculated for each method with the aid of a spreadsheet program (Multiplan) on the Burroughs computer system used at AFIT. Definitions of terms used in the following paragraphs, along with a listing of all the input data used and a comparison of all the results are included in Appendix C.

A sample of the results will be presented here to aid in the discussion of results. The sample of results presented in Table I are based on NSN 5840-00-572-1617 which had a total of 37 failures over 18 data months. (Recall the operating hours are based on 12 units operating 8 hours a day for 18 months.)

TABLE I

Demand Computation Results

STANDARD DEMAND RATE = .13223

| % OFFT | ONT RATE | OFFT RATE | TOTAL RATE |
|---|---|---|---|
| .00 | .1027778 | .0000000 | .1027778 |
| .02 | .1007222 | .0000587 | .1000781 |
| .05 | .0976389 | .0001468 | .0977857 |
| .10 | .0925000 | .0002937 | .0927937 |
| .25 | .0770833 | .0007341 | .0778175 |
| .50 | .0153889 | .0014683 | .0528710 |
| 1.00 | .0256944 | .0022024 | .0278968 |

In the AFLC/MMMR method, as the % NOP Fail/% OP Fail ratio increases, the on-time failure rate decreases and the off-time failure rate increases as expected. However, the requirement for the part and the Total Fail Rate both DECREASE, which is not expected and not desired. Given the number of failures did not change, then these two values should have remained reasonably constant.

As a result of the decreasing values, when the off-time failure rate exceeds 50% of the total failures, then the requirement for the part essentially rounds down to ZERO. This means that where a majority of the total failures are found to occur at

power-down or while powered off, then there is no requirement to stock a spare for the item in the WRSK, even though the total number of failures would indicate otherwise.

Discussion of these results with other members of the AFIT faculty led to the following possible explanation for these undesirable trends:

a. The decreasing requirement as the % NOP Fail increases may be due to the way the Outime hours (Dp) is weighted in the formulas. The value 1-Dp is so much larger than Dp in the formulas, that even though the off-time failure rate increases, it does not increase to the magnitude that the on-time failure rate decreases. Therefore, the on-time failure rate carries more weight in the requirements formula, and always overshadows the impact of an increasing off-time failure rate. The on-time and off-time distributions should be independent, but the AFLC/MMMR requirements computation treats them as mutually exclusive, and thus, dependent. The formulas for the on-time failure rate and the off-time failure rate are essentially identical, except for the weighting of Dp. The mutually exclusive results are then summed to arrive at a requirement. By treating them as dependent, the weighting of Dp is causing the on-time failure rate to always be more powerful than the off-time failure rate, and hence the final requirement is based more on the value of the on-time failure rate than the off-time failure rate.

b. Because the on-time failure rate carries more weight, as it decreases with the decrease in the # OP Fail, then the requirement decreases as well, instead of remaining constant.

AFLC/MMMR continues to assess the dual distribution method. They have modified the formulas to make the distributions independent, and have sought AFIT faculty/graduate student support to validate and verify their revised formulas. Until an adequate dual distribution method is validated, the straight line method used by Mabe and Ormston should by used when computing CE system failure rates.

Sortie Equivalent. Tactical aircraft squadrons are typically tasked and evaluated on their ability to generate aircraft sorties, where a sortie is defined for each aircraft as flying into a target area, engaging the enemy in some fashion and returning to the home base to be prepared for another sortie. The number of sorties flown multiplied by the duration of each sortie determines the number of flying hours for an aircraft each day. These figures can be aggregated at each base to determine the total number of hours flown at that location. For aircraft systems, the generation of demands for the majority of parts on the aircraft is dependent upon the flying hour intensity. Thus, the number of failures generated each day at each base should be a function the total flying hour program. Dyna-METRIC computes failures in just this manner. The number of failures for each part is computed on a daily basis according to the following formula:

$$\text{Total demands} = \text{Demand Rate} \times \text{Aircraft} \times \text{Sorties/day} \times \text{Sortie Duration} \times \text{QPA} \times \text{Application Fraction}$$

Note that the Quantity Per Aircraft and the fraction of aircraft equipped with a part are used to adjust the total number of failures to an appropriate level.

CE equipment does not fly sorties, therefore, the applicability of this method of generating failures must be evaluated. As discussed earlier, the primary factor driving demands for CE equipment is the amount of operating time. If operating hours can be equated to flying hours, Dyna-METRIC should be able to compute an appropriate number of demands for CE systems. Sorties and sortie duration are demand generating variables unique to aircraft and the product of these two variables determine the number of hours each aircraft will fly in a day. These two variables can be redefined so that the resulting product represents the number of hours each CE unit operates without affecting the computational process of the model.

The most logical means of accomplishing this is to define a sortie as an operating cycle for CE units whose duration will be specified by the sortie duration variable. However, there are many possible combinations of these two variables that all result in the same product. The question remains, then, as to what combination should be used in analyzing CE systems. Any of the combinations will result in the same number of demands generated, which also will result in the same number of expected NFMC units. From the number of FMC aircraft (1-NFMC aircraft), Dyna-METRIC computes the expected number of sorties. Since the expected

number of sorties is the output measure most sensitive to changes in these input variables, the selection of a combination of these sortie inputs should be based on which one makes it easiest for the user to interpret output in terms of CE operation.

In order to evaluate the best method of modeling the operation of CE equipment, several combinations of sorties and durations were studied in separate runs of the Dyna-METRIC model. Rather than evaluate all possible combinations, four combinations across the range of possible values were analyzed. The authors felt that this would be sufficient to demonstrate the relationship between the input variables and the sortie output measure. The following figure shows the alternative sortie definitions that were studied.

```
 1 Sortie/24 Hours Duration = 24 Operating Hours
 6 Sorties/4 Hours Duration = 24 Operating Hours
12 Sorties/2 Hours Duration = 24 Operating Hours
24 Sorties/1 Hour  Duration = 24 Operating Hours
```

Figure 8. Alternative Sortie Definitions

As mentioned earlier, the number of operating hours remains the same in all four alternatives, thus the number of demands each day remains constant. The question that remains, then, is which alternative produces output which is easiest to interpret in terms of CE operations. The Dyna-METRIC output for each of the alternatives was identical in terms of the expected number of NFMC units, total backorders and problem parts. However, the expected number of sorties and the derived number of operating hours did change. Table II displays these results for one sample

base in the Dyna-METRIC scenario. The number of operating hours (a meaningful measure relative to CE systems) is computed by multiplying the expected sortie value from Dyna-METRIC by the sortie duration specified in the input file. Operating hours have to be computed by the user external to the model.

TABLE II

Sortie Definition Results

| DAY | 24/1 SORTIE/OPERATING HOUR | 12/2 SORTIE/OPERATING HOUR |
|---|---|---|
| 1 | 23.93 / 23.93 | 11.96 / 23.92 |
| 3 | 23.93 / 23.93 | 11.96 / 23.92 |
| 5 | 23.50 / 23.50 | 11.75 / 23.50 |
| 7 | 22.62 / 22.62 | 11.31 / 22.62 |
| 10 | 21.86 / 21.86 | 10.93 / 21.86 |
| 15 | 20.21 / 20.21 | 10.11 / 20.21 |
| 20 | 17.76 / 17.76 | 8.88 / 17.76 |
| 25 | 14.70 / 14.70 | 7.35 / 14.70 |
| 30 | 11.56 / 11.56 | 5.78 / 11.56 |

| DAY | 6/4 SORTIE/OPERATING HOUR | 1/24 SORTIE/OPERATING HOUR |
|---|---|---|
| 1 | 5.98 / 23.92 | 1.00 / 24.00 |
| 3 | 5.98 / 23.92 | 1.00 / 24.00 |
| 5 | 5.88 / 23.52 | .98 / 23.52 |
| 7 | 5.66 / 22.64 | .94 / 22.56 |
| 10 | 5.47 / 21.88 | .91 / 21.84 |
| 15 | 5.05 / 20.20 | .84 / 20.16 |
| 20 | 4.44 / 17.76 | .74 / 17.76 |
| 25 | 3.67 / 14.68 | .61 / 14.64 |
| 30 | 2.89 / 11.56 | .48 / 11.52 |

As the results indicate, the number of expected sorties never exceeds the requested number of sorties per aircraft/unit. This is because there is only one unit at each base which is capable of generating sorties and the sortie rate specified in the input is the required number of sorties per unit. Similarly,

the expected number of sorties varies from one Dyna-METRIC run to another by a factor of the requested number of sorties per unit. For example, in the run that specified 24 sorties of one hour duration, the expected sorties start out close to 24 on day one and taper off to 11.5 at day 30. In the run with 12 sorties of 2 hour duration, the first day achieves about 12 sorties and tapers off to about 6 on day 30; a factor of 1/2 where we asked for only 12 sorties per unit instead of 24. The same holds true for the remaining two runs.

Notice that the changes in the expected number of operating hours are quite different. Remember, the operating hour measure is the Dyna-METRIC computed expected number of sorties times the the sortie duration for each run. The expected number of operating hours remain relatively constant across the four runs. There are some differences, but none exceed .08. In terms of the accuracy of this measure, the difference is insignificant, and much of the it is due to rounding. These results demonstrate that it makes no significant difference what combination of sortie and sortie duration you specify because the important value is the product of the two, daily operating hours, which remains constant. Given these results, the user should specify 24 sorties of 1 hour duration which represents the maximum number of hours a unit can operate each day. In this way, the Dyna-METRIC computed expected sortie value represents the number of hours the unit should be able to operate, and the user does not have to multiply the expected sortie value by the duration to come up with the desired output measure (operating hours).

Operational Unit Definition. Dyna-METRIC was designed to model primarily tactical aircraft where squadrons of aircraft are assigned to bases and the performance of the aircraft at each base is evaluated. At each base, each aircraft (operational unit) is considered to be identical to all others (a single MD) and therefore interchangeable with all other aircraft (to allow cannibalization). The structure of CE equipment is notably different. This requires redefinition of what the user models as an aircraft, or more generically, an operational unit. In terms of model inputs, the user must assign the number of aircraft at each base, or fleet size, and adjust the parts that are included in the data file to reflect all of the parts of interest for the operational unit defined.

In the CE world, an operational unit is an homogeneous system which provides some functional capability (radar coverage, communications, etc.). However, such an entity is typically composed of several major end items or MDSs. Recall that a mobile Forward Air Control Post (FACP) consists of radar, operations shelters, power, communications and vehicles. Each of these is considered a separate MDS. Each MDS is managed and supported independently of the others, to include having a separate WRSK kit to support its wartime mission. This structure somewhat complicates the definition of an operational unit, since Dyna-METRIC can only model one MD per base.

Given this structure of CE units, there are several alternative aircraft/operational unit definitions that can be

with its own Dyna-METRIC data file. In this approach, there would b- only one operational unit (aircraft) at each base and all the parts that are included in the WRSK to support this MDS would be included in the data file. This requires one computer file and Dyna-METRIC run to get a performance report on the capability of each MDS or component of the overall operational unit. With this approach, however, the user must evaluate the reported capability of each component and infer (external to model computations) what the capability of the operational unit as a whole would be (in terms of NFMC units and expected hours of operation).

A second alternative would be to model each MDS at a separate base within a single Dyna-METRIC run, where the data base is a single pool of all the assets belonging to all the modeled MDSs. In this approach, there would be one base in the scenario for each MDS, and each base still has only one operational unit assigned to that base. The application fraction feature of Dyna-METRIC would be used to assign the parts applicable to each MDS to the appropriate base. This alternative only requires one file and one run of the model, but it has the same problems of inferring capability from separate reports of capability for each component of the aggregate operational unit.

A final alternative would be to roll up all of the component MDSs and consider them to be a single operational unit at a single base. All of the parts from the individual MDSs would be lumped together into a single data file. With this approach, Dyna-METRIC would evaluate the performance of the entire opera-

tional unit as a function of all of its component parts. The user would only have to determine which component MDS has malfunctioned (by evaluating the problem parts list) and determine mission capability status by applying appropriate NATO standards. This approach requires the least amount of computer files and run time, as well as simplifying the interpretation of output. However, it does not exactly model the CE environment as it is actually structured.

If Dyna-METRIC results do not differ significantly between these alternative approaches, then the user would want to use the alternative that makes analysis easiest. This research evaluated the two extremes, alternative one where each MDS has a separate run against alternative three where all of the MDSs are considered to make up a single composite radar unit at one base. The output from the two alternatives was identical in terms of identification of problem parts and performance of individual items. However the expected number of NFMC aircraft and sorties were different. The results are displayed in Table III.
The values under the composite column represent the total NFMC units and operating hours for all six bases as computed by Dyna-METRIC in a single run. The values listed under the "SEPARATE" column represent the total NFMC units and operating hours for all six bases summed from seven separate runs representing the seven end items modeled.

The results show little difference in NFMC units or operating hours in the first ten days, and then the expected NFMC units gradually increase in the separate run up to day 30 when

## TABLE III

Operational Unit Definition Results

EXPECTED (NFMC) UNITS COMPARED TO TARGET (0)

| DAY | COMPOSITE | SEPARATE |
|---|---|---|
| 1 | .003 | .003 |
| 3 | .081 | .081 |
| 5 | .214 | .213 |
| 7 | .349 | .348 |
| 10 | .589 | .589 |
| 15 | 1.041 | 1.056 |
| 20 | 1.659 | 1.736 |
| 25 | 2.415 | 2.648 |
| 30 | 3.188 | 3.694 |

SHORTFALL FROM REQUESTED OPERATING HOURS

| DAY | COMPOSITE | SEPARATE |
|---|---|---|
| 1 | .07 | .07 |
| 3 | 1.94 | 1.93 |
| 5 | 5.12 | 5.12 |
| 7 | 8.37 | 8.36 |
| 10 | 14.13 | 14.16 |
| 15 | 25.00 | 25.38 |
| 20 | 39.80 | 41.69 |
| 25 | 57.95 | 63.56 |
| 30 | 76.51 | 88.68 |

there is .506 more grounded units across the six bases. Correspondingly, as there are more grounded units in the separate run, there is a greater sortie shortfall where 12.17 less operating hours are achieved across the six bases on day 30. The NFMC units and operating hours differences are related by the user-specified maximum operating hour rate. In this case, each unit was allowed to operate 24 hours per day maximum and an additional

.5 units should be able to generate approximately 12 (.5 units x 24 hour/day) additional operating hours.

The results of the separate runs tend to be more pessimistic than the composite run. For the 30 day time period evaluated, the differences in the runs are noticeable and may become more extreme over a longer period of analysis. However, the differences are not so great so as to restrict the CE community from using either approach, where the choice could be based on a tradeoff between the cost and effort of manipulating data for the different file structures and the small difference obtained in results. Note that the differences in the outputs can be explained by the way Dyna-METRIC computes NFMC aircraft and sorties. The output describing problem part performance is the same because these are part specific computations. The NFMC aircraft is a probability distribution obtained by taking the product of individual item backorder distributions. As the base of parts within a run is changed the product of the distributions will change; thus, seven runs with a subset of the total components will be different than a single run containing all the components.

<u>Quantity Per Application</u>. CE systems typically have a lot of redundant capability. Many components are installed in the operational units in high quantities (QPA), where the unit is still mission capable with only one or two of the applications functional. Version 4 of Dyna-METRIC has a feature to model this situation. Assessment results are likely to be sensitive to the

ability of the model to represent these redundant systems. This research evaluated the new Minimum QPA feature of Dyna-METRIC to determine the sensitivity of results to variations in this input parameter. This information should establish the criticality of obtaining correct data elements for systems which have redundancy.

This research evaluated several combinations of total QPA versus Minimum QPA for a single item that was a borderline problem part in the original run. The total QPA was held constant, since changing it simply increases the total number of demands and the pipeline quantities for the item. On the other hand, the minimum QPA was varied across the range of possible values, since the minimum QPA specifies the level where shortages will start to ground the units (i.e., determines the amount of redundancy). The combinations that were evaluated are shown in Figure 9.

| | |
|---|---|
| Total QPA = 8 | Minimum QPA = 2 |
| Total QPA = 8 | Minimum QPA = 4 |
| Total QPA = 8 | Minimum QPA = 6 |
| Total QPA = 8 | Minimum QPA = 8 |

Figure 9. Combinations of Total QPA versus Minimum QPA

The performance of individual parts (in the problem parts listing and pipeline report) remain identical in terms of the expected number of assets in the various pipelines and expected backorders. Changes did occur in the expected number of NFMC units and operating hours, and when the test item was identified as a problem part. The results in Table IV represent a sample output from one of the six bases in the scenario.

TABLE IV

QPA Sensitivity Results

EXPECTED (NFMC) UNITS

| DAY | TOTAL QPA / MINIMUM QPA 8/2 | 8/4 | 8/6 | 8/8 |
|---|---|---|---|---|
| 1 | .000 | .000 | .000 | .000 |
| 3 | .003 | .003 | .003 | .010 |
| 5 | .021 | .021 | .026 | (.120) |
| 7 | .043 | .045 | .075 | (.291) |
| 10 | .077 | .092 | .191 | (.524) |
| 15 | .145 | .209 | (.417) | (.764) |
| 20 | .245 | (.365) | (.615) | (.884) |
| 25 | .371 | (.528) | (.761) | (.943) |
| 30 | (.504) | (.667) | (.857) | (.972) |

() Indicate when part is identified as a problem

EXPECTED OPERATING HOURS

| DAY | TOTAL QPA / MINIMUM QPA 8/2 | 8/4 | 8/6 | 8/8 |
|---|---|---|---|---|
| 1 | 24.00 | 24.00 | 24.00 | 24.00 |
| 3 | 23.93 | 23.93 | 23.92 | 23.75 |
| 5 | 23.50 | 23.50 | 23.37 | 21.12 |
| 7 | 22.97 | 22.92 | 22.20 | 17.02 |
| 10 | 22.15 | 21.79 | 19.43 | 11.44 |
| 15 | 20.51 | 18.98 | 14.00 | 5.67 |
| 20 | 18.13 | 15.24 | 9.24 | 2.79 |
| 25 | 15.08 | 11.34 | 5.73 | 1.36 |
| 30 | 11.90 | 7.99 | 3.44 | .67 |

The results demonstrate that NFMC units and operating hours vary significantly as the minimum QPA is varied. As the minimum QPA approaches the total QPA, the probability of the single unit being non-operational increases (this is the expected number of NFMC units when there is only one unit per base), and correspondingly less operating hours are achieved. The magnitude varies

from no change on day one to a 46.8% increase in the probability of the unit being non-operational and an associated 94.4% less operating hours on day 30 (when the two extremes are compared). Notice also that as the minimum QPA approaches the total QPA, the item is identified as a problem item earlier and earlier. The reason these differences occur in the expected NFMC values and not part performance is because the model only considers QPA when it determines how the backorders (holes) for the various parts are to be distributed across the fleet of aircraft. As mentioned before, the expected operating hours are derived from the number of available units, and consequently it changes accordingly. The identification of problem parts varies also, because Dyna-METRIC computes the probability of achieving your NFMC goal, and the number of NFMC units compared to this target determines this probability. Whenever the probability drops below the user specified confidence level, problem parts will be listed.

These results indicate that the output results are quite sensitive to the minimum QPA, on a part by part basis. To the degree each part has an incorrect minimum QPA, its affect on overall weapon system capability will be overstated or understated; either way, the results are inaccurate. Therefore, it is very important that users determine the proper minimum and total QPA for each part. In the real world, the determination of minimum QPA would most often be based on Minimum Essential Subsystem Listings or similar standards, which very often can be subjective and situation dependent. This tends to make the task of specifying minimum QPA values difficult. In any case, the user should be aware of the effect of incorrect values.

Modeling Mobility. Mabe and Ormston were the first to use Dyna-METRIC options 10 and 16 on AFLC's CREATE computer (version 4.3). The subroutines had to be specially loaded by AFLC/XRS for their use. When Mabe and Ormston began generating erroneous results, AFLC/XRS through consultations with Rand, were eventually able to isolate the problem to a coding error which caused the pipeline to be discontinuous. However, it was corrected too late to be included in their TACS research. Subsequent AFIT students attempted to use the options after version 4.4 had been released, and ran into additional problems getting them to work properly. When the model was executed for this research, it was believed that all the bugs had been worked out so that the options would work as advertised. The results in Tables V and VI demonstrate the continuity in pipelines that can be achieved from one run to the next. Results are displayed at the end of the first run (day 30) and the beginning of the second run (day 31). Table V shows changes at all bases in selected measures of performance, total backorders and expected number of NFMC units. Table VI displays component level output that shows the various pipeline segments computed by Dyna-METRIC. Again, data is displayed on day 30 of the first run and day 31 from the second run. Results are listed for several sample parts, two that were identified as problem parts and two that were not (the data was obtained from an optional pipeline report).

The results in Table V show that the total backorders for each base on day 31 differ from the level on day 30 by only a

small amount, some increasing and some decreasing. Day 30 values represent the status at the end of the day, as do the values for day 31. Therefore, these differences represent one additional

Table V

Pipeline Continuity - Base Performance Results

BASE PERFORMANCE

| BASE | TOTAL BACKORDERS DAY 30 | TOTAL BACKORDERS DAY 31 | E(NFMC) DAY 30 | E(NFMC) DAY 31 |
|---|---|---|---|---|
| 606C | 6.80 | 7.11 | .504 | .501 |
| 609C | 6.99 | 7.36 | .518 | .536 |
| 626F | 5.54 | 5.85 | .545 | .510 |
| 636F | 5.42 | 5.71 | .535 | .496 |
| 619F | 5.49 | 5.85 | .537 | .514 |
| 629F | 5.63 | 6.01 | .549 | .530 |
| TOTAL | 35.86 | 37.89 | 3.188 | 3.087 |

day of flying and repair activity. The magnitude of the changes are reasonable for this amount of activity, as determined by the trends for each part established throughout the run (not shown). There are similar changes observed for the expected NFMC units. Note that increased total backorders does not always yield increased NFMC units. This is because total backorders is the sum of expected backorders for all parts, where some parts will experience an increase and some will experience a decrease. On the other hand, only those items with the most severe shortages (backorders) weigh most heavily in determining the expected number of NFMC units. Therefore, the top few critical items may have a decrease in backorders (with an associated decrease in

NFMC units), while across all the parts there is an overall increase in total backorders. Table VI depicts this situation by displaying the various pipeline segments for selected individual parts. It further demonstrates that individual pipeline segments for components can either increase or decrease on each day.

TABLE VI

Pipeline Continuity - Component Level Results

PIPELINE STATUS (PROBLEM PARTS)

| BASE 606C | 5820-00-921-6565 | | 5840-01-035-1166 | |
|---|---|---|---|---|
| PIPELINE | (DAY 30) | (DAY 31) | (DAY 30) | DAY 31 |
| ADMIN | 0.195 | 0.195 | .025 | .030 |
| REPAIR | 5.311 | 5.435 | .050 | .050 |
| AWP | 0.000 | 0.000 | .000 | .000 |
| ORDERED | 0.930 | 1.128 | .822 | -.380 |
| TOTAL | 6.436 | 6.758 | .897 | -.300 |
| STK | 2.0 | 2.0 | 1.0 | 1.0 |
| BACKORDERS | 4.450 | 4.768 | 0.305 | 0.000 |

() indicate days when part was identified as a problem

PIPELINE STATUS (NON-PROBLEM PARTS)

| BASE 619F | 5820-00-917-6578 | | 6110-00-442-7488 | |
|---|---|---|---|---|
| PIPELINE | DAY 30 | DAY 31 | DAY 30 | DAY 31 |
| ADMIN | 0.03 | 0.03 | 0.05 | 0.05 |
| REPAIR | 0.30 | 0.30 | 1.02 | 1.11 |
| AWP | 0.00 | 0.00 | 0.00 | 0.00 |
| ORDERED | 0.58 | 0.62 | 0.66 | 0.00 |
| TOTAL | 0.90 | 0.95 | 1.73 | 1.16 |
| STK | 2.0 | 2.0 | 4.0 | 4.0 |
| BACKORDERS | 0.08 | 0.09 | 0.04 | 0.01 |

The first half of the table shows the two problem items listed as problem items at the end of day 30. Notice that part 5840-01-035-1166 is no longer a problem at the end of day 31. The results might suggest that parts which were on order arrived on day 31 and reduced that portion of the pipeline sufficiently to eliminate its backorders; thus, this part no longer degrades unit performance and is not listed as a potential problem. However, the reduction is due to a negative value in the "ordered" segement of the pipeline, which is an incorrect and undesireable result. Once again, AFLC/XRS investigated the problem and could not quickly identify the source of the problem. After several weeks of research, the problem was referred to personnel at Rand. Rather than delay finalization of this report any further, the results have been displayed with their errors, since the potential of these options could still be presented.

The second half of Table VI shows the pipeline computations for selected components that were not identified as problems. This information on all components for each day of analysis can be obtained at the option of the user by specifying option 15 in the input file. These selected components further support the findings established above. Notice that the stock level is used to offset the pipeline quantity to determine the expected number of backorders for each part.

The results obtained from the use of options 10 and 16 (although the exact values may be incorrect) indicate that these options can be used to further enhance the flexibility of Dyna-METRIC. By saving the ending pipeline status and starting

subsequent runs from that point, the user can greatly extend the time period to be analyzed, but more importantly, he/she can also change any model variables between runs. Although Dyna-METRIC inherently provides for time dependent changes in many variables that would most likely change, it does not provide that flexibility across all variables (as it would be impractical and/or infeasible to do so). Nevertheless, through careful use of these options a user can successfully change variables that are important for special purposes, such as the varying pipelines to model the mobility of the TACS.

## Summary

This chapter presented the results of research to develop a methodology for applying Dyna-METRIC to non-aircraft systems. This effort was a follow-on to Mabe and Ormston's (1984) modeling of the mobile Tactical Air Control System in Germany. The research evaluated ways to redefine aircraft-oriented input variables and output measures, as well as the evaluation of the importance of other model variables and features important to non-aircraft applications.

The results of the research indicate that a simple demand rate computation of demands divided by operating hours is adequate, and probably the best to use at this point in time. A dual distribution approach (for on-time and off-time failures) may be appropriate and more accurate for CE type equipment, but an appropriate and reliable formulation needs to be developed.

Sorties can be treated as operating cycles, where this variable, along with the duration of the operating cycle, determine the number of failures each day. The best ratio of cycles to duration is 24 cycles of 1 hour duration; this equates to 24 possible hours of operation per day. The expected number of sorties in the output then represents the expected number of hours a unit can operate.

The way a user defines an operational unit affects the outputs generated by Dyna-METRIC. Modeling each end item of a CE system as a separate unit at a separate base gives slightly greater capability estimates than considering all the end items as a single composite unit at a base. Assigning a single unit to each base also requires some special interpretation of output measures.

The minimum QPA is a critical variable for units with redundant capability; therefore, the proper configuration and mission essentiality of these components needs to be determined. In situations where the user is trying to model complex scenarios, options 10 and 16 increase the flexibility of the model to represent dynamic changes. Almost any model variable can be changed between separate runs that are tied together by a continuous pipeline through the use of these options. Modeling the varying distances between deploying units and their sources of supply is an example of the potential use of this capability.

By using the approaches evaluated in this chapter, Dyna-METRIC users should be able to successfully apply the model to a variety of CE systems. Although the basic approach described can

be utilized, special applications of the model may require additional techniques that have not been covered in this research. The model has tremendous inherent flexibility, but users must always carefully assess the appropriateness of adjustments and assumptions that must be made to get the model to represent non-aircraft weapon systems and scenarios. The next chapter will extrapolate the results of this research and discuss the feasibility and nature of applying Dyna-METRIC to non-aircraft systems beyond the experience with the TACS.

# Chapter IV

## Analysis of Potential Non-Aircraft Applications

### Overview

This chapter discusses the potential use of Dyna-METRIC for ballistic missile systems, space systems, transportation systems, and civil engineering systems. The portion on ballistic missile systems is based on AFIT thesis research completed in 1985 by Captain Stephen G Hearn. The portions on space, transportation and civil engineering systems are based on generalizations from the work done with the mobile TACS. No additional Dyna-METRIC analysis was made using data specifically related to the space, transportation or civil engineering systems discussed.

### Ballistic Missile Systems

Hearn (1985) studied the feasibility of using Dyna-METRIC on Intercontinental Ballistic Missile (ICBM) systems. His purpose was to evaluate the ability of Dyna-METRIC to model the important features of ICBM operations, and to produce reasonable assessment results and requirements computations. As an initial effort to demonstrate these capabilities, Hearn chose to evaluate the guidance system of the Minuteman III weapon system. He chose Minuteman III because of the availability of data, and he concentrated on the guidance system because it is the only system which operates continuously. He did not attempt to use the model to evaluate the performance of dormant components on the missile. Hearn evaluated the day to day operation of all the bases assigned Minuteman III missiles for a period of one year.

Data Availability. As noted before in the TACS study, one of the difficult aspects of using Dyna-METRIC for new applications is obtaining necessary data. This proved to also be the case for missile systems. The Dyna-METRIC data file was manually constructed with data obtained from various sources. The component descriptive data (repair cycle time, order and ship times, NRTS rates, etc.) were obtained from D041, the demand data and LRU stock levels were obtained from Ogden ALC, while SRU stock levels came from the standard base supply system at the Aerospace Guidance and Metrology Center (AGMC) at Newark AFS OH. Information about the depot repair process was also obtained from AGMC and general scenario information was obtained from the Strategic Directorate of the Logistics Operation Center at AFLC and Ogden ALC.

Model Structure. The data obtained from these various sources were then structured into the model to represent the daily operation and support of the missile wings. Four separate bases were modeled, with each assigned from 50 to 250 missiles. The bases had no intermediate maintenance capability for the guidance components and were not allowed to cannibalize components from one missile to another. Resupply from the depot was available throughout the scenario.

AGMC was modeled as the depot which provided all maintenance activity on the components for the bases. The depot was able to obtain resupply from industry after a specified lead time.

A unique feature of the guidance system on missiles is that it is composed of a single LRU made up of approximately 130 SRUs.

This was the largest known LRU/SRU ratio ever used in Dyna-METRIC and it required some adjustments to CREATE job control language to adjust various parameters in order for the model to run without error and within a reasonable time period. Another unique characteristic of the guidance system its overall high reliability. Only 47 of 131 SRUs modeled had any history of demand experience. Those which had experience were so low that the demand per operating hour had to be entered in scientific notation (to go beyond six significant digits).

It was necessary to define aircraft specific variables in terms of missiles, similar to what was done for the TACS; however, the approach was more straight forward. Each wing is composed of many missiles (50 to 250), just as aircraft wings have many aircraft. Thus, Hearn treated each missile as an aircraft, and defined sorties as operating cycles of one hour duration. In this way, demands were generated as a function of operating hours, where each guidance system was programmed to operate 24 hours each day.

Experiments. After collecting reasonable data and structuring it in such a way as to depict ICBM operations, Hearn ran several experiments to evaluate the ability of the model to represent important aspects of missile logistics support. The wartime environment is essentially no different that its peacetime environment, that is, the missile is in constant readiness until launch when we can no longer affect the outcome. Therefore, assessing missile systems consists of predicting failures and problem parts that degrade its readiness. An assessment from

the current day up to some point in the future must consider the pipeline status that exists at the beginning of the time period.

Dyna-METRIC normally starts the first day of a run with no assets in the various pipelines, and it normally takes some period of time before they reach a normal, steady-state level. This tends to skew results in situations where many assets would be in various stages of repair at the very beginning of the scenario. Hearn utilized the peacetime pipeline feature of Dyna-METRIC, which starts the scenario with a peacetime steady-state level of assets in the pipelines.

Since the guidance system is so reliable, very few failures were expected and Hearn anticipated that a long period of analysis would be necessary before any degradation in capability would be observed. To evaluate methods of conducting extended analysis, Hearn compared the use of options 10 and 16 with the new automatic time scaling feature of version 4.4. Hearn conducted a final analysis to evaluate applicability of Dyna-METRIC's requirements computation mode for missile guidance components.

Results. Hearn was one of the first to use the peacetime pipeline in version 4.4, and there were some problems that led to unexplainable results. The problems were not corrected at the time his research was completed, but were under further evaluation by AFLC/XRS. New problems with options 10 and 16 occurred which gave greatly different results from the time scaling feature. The results from the automatic time scaling appeared to be reasonable. Options 10 and 16 are designed to provide the same capability, although it is somewhat more cumbersome to utilize.

As mentioned before, options 10 and 16 have the added advantage of allowing variable changes; therefore, whichever method best meets the needs of the user could be selected.

Hearn made parallel Dyna-METRIC runs on the World Wide Military Command and Control System (WWMCCS) computer to validate model results with real world performance. Although not documented in his thesis (due to classification), he compared the results generated on the WWMCCS with actual missile performance, and found a reasonable approximation. The Dyna-METRIC model is as applicable for computing guidance requirements as it is for making ICBM capability assessments. With the parameters used in this research, the requirements computation showed that no stock was required to meet the acceptable level of NFMC missiles.

## Space Systems

Any space based, or ground based $C^3$ system can be evaluated with Dyna-METRIC in much the same way as Mabe and Ormston evaluated mobile radar units. The critical questions of what constitutes an operating cycle, and where the demand data related to the cycle can be obtained still need answers. However, the space environment is much more complex than any other $C^3$ system environment. The answers to the above questions are not easily found, and must address each segment of the space logistics environment.

In January 1983, the Air Force Logistics Command, through their Sacramento Air Logistics Center, published the USAF Space Logistics Concept Study (5). This landmark document discussed

the space environment and related logistics support issues. Budde and Mabe used this study as the basis for assessing the applicability of Dyna-METRIC to the space environment (4). The following discussion reports the results of their analysis, which is an extension of the logic used to study CE systems. Note: the conclusions drawn with respect to the space environment are extensions of the conclusions drawn for CE systems; no actual component or scenario data on the space environment was analyzed, nor were any runs of the model made specifically to assess Dyna-METRIC's utility to the space environment.

The Space Logistics Concept Study described four basic segments of the space environment:

1. the Launch Segment - boosters, space launch vehicles, associated processing and pad facilities, and range systems (5:IV-1).

2. the Space Segment - satellites, payloads, and platforms placed into orbit (5:V-2).

3. the Control Segment - the tracking, telemetry, and command (TT&C) facilities and systems used to monitor orbiting space segment systems, or to change their performance or orbit. This segment includes antennae, receivers, transmitters, automated data processing equipment, display systems, and other associated communications systems, both fixed and mobile (5:VI-1).

4. the User Segment - the terminal facilities used to gather and interpret both space-based and ground-based sensor

data, then generate and distribute useful products based on the data. This includes facilities to receive and interpret weather data, communications data, or navigational data (5:VII-1).

Dyna-METRIC could be used to assess communications-electronics end items in any of these segments. However, the research described in Chapter Three of this report can most easily be extended to the User and Control Segments. These two segments use end items most similar in design and mission to the systems assessed in the mobile TACS (i.e., radios, radars, associated signal processing equipment, and automated data processors). Currently, these two segments are at least partially supported by AF Logistics systems, and have the most potential for actual assessments by the Dyna-METRIC model.

The following discussion of these two segments will first address the equipment operating cycles and sources of demand data, then potential limitations on applying Dyna-METRIC.

Control Segment. The TT&C systems comprising this segment can be further subdivided into operational/programmed systems, and system dedicated/common-user systems. Operational systems are currently in operation performing a TT&C mission. Programmed systems are in some phase of the acquisition process. Systems dedicated systems are specifically assigned to the TT&C of one unique space segment orbiting system, with little or no application to other orbiting systems. Common-user systems provide TT&C as either a primary or back-up facility to a variety of space segment orbiting systems through a common-user net (such as the Air Force Satellite Control Facility) (5:VI-1).

The best operating cycle for the equipment supporting the Control Segment mission is probably operating hours. However, because of the unique operations of these systems in providing TT&C, a new category of operating time needs to be introduced, "stand-by." These facilities can only support an orbiting system within a certain tracking and control window. As the system orbits and enters the window, TT&C equipment is fully powered up and cycling. As the orbiting system leaves the window, the equipment remains powered on, but is placed in a stand-by mode. In stand-by there is no transmission of tracking signals, nor passing of control commands. Because of this operating cycle based on the tracking and command window, on-time and off-time take on new meanings, and are modified by stand-by time.

Demand data to support the operating cycles could be very hard to gather and format for use in the Dyna-METRIC model. Maintenance on the systems ranges from 100% Air Force organic to 100% contractor provided (5:VI-5). Contractors are not required to track and support supply data on reparable spares such as the data required by the Air Force Standard Base Supply System, or AFLC's D041 program. For this reason, the demand data for systems having contractor repair may not be available to the Air Force.

Further compounding the data problem is the diversity of the equipment and operational requirements. Both fixed and mobile facilities support the TT&C mission; however, they do not all operate under a standard scenario or single MAJCOM (5:VI-7). As a result, it is difficult to speak of an operating cycle for the

systems, and be sure the cycle is similar in all systems. Operating hours in a fixed systems may include just the time orbiting hardware is in the tracking and control window. In a mobile system, it may include all time the system is not redeploying or completely powered off.

Using options 10 and 16 allows Dyna-METRIC users to simulate the deployment of mobile systems, so movement is not a problem. The real problem with gathering and formatting data for the control segment lies in the non-standard operations and multiple types of operating/non-operating cycles.

The USAF Space Logistics Concept Study (5) recommends two actions that may help to alleviate some of the problems mentioned above. The first is to standardize support methods (5:VI-10). While varying methods of support may be in order for developing systems, economies of scale and cost savings can be realized by standardizing the method of support for as many systems as possible. AFLC then needs to ensure that demand data is gathered and stored for the spares supporting the TT&C end items. Having standardized support methods facilitate the gathering of data by allowing spares managers to specify in one document the data required and how to gather and transmit it to AFLC.

Next, consolidate and integrate operations (5:VI-10). This will eliminate duplication of support requirements, clarify support lines of communication and facilitate gathering and storage of demand data.

User Segment. The equipment supporting the user segment mission can be divided into four mission areas (5:VII-1):

1. Tactical warning and attack assessment mission, supported by the Ballistic Missile Early Warning System (BMEWS), PAVE PAWS and Cobra Dane facilities.

2. Communications mission, supported by the AF Satellite Communications System (AFSATCOM) and the Defense Satellite Communications System (DSCS).

3. Environmental monitoring missions in support of the Defense Meteorological Satellite Program (DMSP).

4. Navigational and positioning missions supporting the programmed NAVSTAR Global Positioning System (GPS) and the Search and Rescue Satellite Aided Tracking System (SARSAT).

The best operating cycle for these systems is also probably operating hours. These systems use end items of equipment similar in design and purpose with the TACS equipment, and with the Control Segment (i.e., radios, radars, and automatic data processing equipment). Because the information received and processed by the ground stations originates primarily from orbiting hardware, the problem of stand-by time while the hardware is out of the envelope also occurs in these systems. However, some of the User Segment ground stations monitor satellites in geosynchronous orbit, and are essentially operating (with fully operational on-hours) 24 hours a day.

Gathering demand data to support operating hour cycles could also be a problem in the user segment. These systems are frequently unique, one-of-a-kind stations with maintenance ranging from 100% Air Force to 100% contractor provided (5:VII-2). The majority are fixed, but some mobile user segment equipment is

also in use. The impacts of the mixed maintenance concepts, and the multitude of end items in use are much the same as with the control segment. Data needed in the model does not exist at the contractor supported facilities. The data generated by the one-of-a-kind facilities may not be enough to support a run of the model. Finally, the diversity of end items and using commands causes the data to be scattered across a number of sources, each with different methods of gathering and storing the data (non-standardized).

## Transportation and Civil Engineering Equipment

Vehicles, materiel handling equipment (MHE), building environmental systems, power stations, barriers, and fire fighting equipment were evaluated to determine their potential for Dyna-METRIC analysis. This portion of the study began by first evaluating the suitability of some of the model assumptions to transportation and Civil Engineering systems, and then the possible redefinition of key model variables in terms relative to these systems. Finally, the authors investigated the availability of data to support Dyna-METRIC analysis.

Assumptions. As discussed earlier, Dyna-METRIC assumes demands are generated at a constant rate described by a Poisson distribution, with the Mean Time Between Demands (MTBD) being exponentially distributed. Pyles explains the Poisson distribution is "robust," which means it can handle quite a bit of deviation from the exponential MTBD, but how much it can handle is probably open to speculation (17). Where clustering or spacing

of demands occur (which violate the Poisson distribution assumptions), then the model can portray demands according to a negative binomial or binomial distribution.

The Poisson distribution may work well with electronic components that exhibit an exponential MTBD, but it may not work well with mechanical components. Vehicle systems are largely mechanical, as are the fire equipment, barriers, and building environmental systems maintained by civil engineering. Wearout of parts in these systems may be other than exponential due to age and heavy use. If systems are experiencing non-constant failures during "burn-in" (evidenced by a decreasing failure rate), or non-constant failures due to age (evidenced by an increasing failure rate), the model may overstate the requirements for spares or understate the capabilities of the system.

The model evaluates repair of items based on pipelines between repair elements. This implies the pipeline structure must be known before the system can be modeled. Much of the maintenance for civil engineering is done by contract. Thus, the Air Force cannot store the associated maintenance data for use in determining future requirements for spares. In other cases, reparable parts generated during vehicle repair may be turned in to a contractor operated parts store, and hence are again removed from the Air Force system of accountability. In either case, details of the pipeline structure are unknown, and data is unavailable to represent them in the model.

Dyna-METRIC computes output measures assuming that full cannibalization of spares from other aircraft is possible.

Cannibalization may not be practiced, or even possible, with vehicle and civil engineering systems. A full cannibalization assumption generally causes the model to overstate the capabilities of the system. Users can specify a "no cann" scenario, but the identification of problem parts is based on "full cann" calculations.

The model assumes sufficient slack service capacity exists to perform maintenance within the average repair cycle time specified for each component. This is not always true, but Hillestad said it will provide valid results as long as average demands remain less than 80% of the service capacity (11). To more realistically portray actual maintenance capabilities, users can incorporate test stands into their scenarios. The model will then assign parts to test stands for repair using brute force queueing logic in a simulation sub-routine. "Test stands" for vehicle maintenance could be as simple as repair bays, or available mechanics.

Even though the assumptions pose some limitations on using Dyna-METRIC for vehicles and civil engineering, the real key to using the model still lies in defining the model variables in terms of the system to be evaluated. Once the variables are defined, then data must be collected and formatted for the variables.

Variable Definitions. As reported in Chapter Three, there are three critical variables in the model that require redefinition for non-aircraft systems. These variables can be successfully redefined for vehicle and civil engineering systems. The definitions are based on how the systems are used.

1. Demand per Flying Hour. This variable is probably best redefined as "demand per operating hour" in most non-aircraft systems. Demand per operating hour could be used with building heating/air conditioning systems, materiel handling equipment, and power generators. For vehicles, however, a better association may be found by equating demands to driving hours; that is, hours when the vehicle is being driven and not just left idleing. This implies the vehicle should be moving during the period when failures occur to accurately describe the failure conditions.

2. Sortie Equivalent. The combination of the number of sorties and the duration of each sortie (hours) defines the operating cycle for the system being evaluated. For systems where demands are generated by operating hours, the best measure of a sortie is "one hour of operating time". This measure allows the user to interpret expected sorties in the output as expected operating hours. Remember that other combinations can be used, but they require the user to multiply the expected sortie output measure by the specified sortie duration to arrive at expected operating hours.

For vehicle systems and possibly MHE, the best definition of a sortie may be a trip. However, a trip in a vehicle may not be standard nor easily defined. One approach is for users to estimate the average number of trips each day (dependent upon type of vehicle) and the average duration of these trips, such as 45 minutes of driving time. This same logic is used to describe aircraft sorties and duration, and could have direct applications to vehicles, if the necessary data is available.

3. Operational Unit. This value is essentially the number of identical systems being evaluated on a base. For vehicles, it is the number of each separate vehicle type (i.e., sedan, 1 1/2 ton truck, M-885). For civil engineering systems it may be more abstract, because a building environmental system may have two or three separate sub-systems. In this case, the best definition of an operational unit is probably the total number of complete systems, as opposed to the total number of sub-systems. Since Dyna-METRIC can assess only one MDS on a base at a time, this aggregate unit definition will allow the model to assess the overall capability of complete systems. However, if users want to assess the capability of a sub-system independent from the overall system, they could model only the sub-system and its associated LRUs and SRUs.

Data Availability. Given that variable definitions pose no limitation in using Dyna-METRIC, Captain Mabe evaluated vehicles, MHE, building environmental systems, and power generators for the availability of data for use model. He interviewed Air Force experts on each of these systems to discuss: 1) possible operating cycles related to demands, 2) available data related to the operating cycles, and 3) current methodologies and systems to track and store demand/failure data. He was specifically looking for definable operating cycles in each system evaluated, and demand data related to the operating cycles. He wanted also to determine if the current methods of tracking and storing demand/failure data could be tapped for Dyna-METRIC input values without a lot of reworking by system users. Here are the results of the interviews, and his evaluation:

1. Vehicles/MHE. Captain Mabe spoke with the Vehicle Management Branch, HQ AFLC. They indicated that vehicle operating data is stored in the Vehicle Integrated Management System (VIMS), and kept for only 13 months of use. The data is updated after the vehicle has driven a certain number of miles, as determined from odometer readings during periodic maintenance or estimates based on fuel consumption. Repair data is tracked by system within the vehicle, and not by individual part number. Each vehicle consists of 42 systems, such as electrical, power train, and wheels. There is no repair cycle for vehicle parts in the Air Force, and most reparable parts are turned into the COPARS store and removed from Air Force accountability and ownership. Mr. Edwards felt either operating hours or trips might work, but no one in the vehicle business speaks in terms of operating cycles, and data is not geared to any definable cycle.

2. Power Generators and Building Environmental Systems. HQ AFLC/DEMG explained specific use data was not tracked on civil engineering systems. Base Civil Engineering units track labor hours, materiel, and job orders on the Base Engineering Automated Management System (BEAMS), but none of this data is geared to any type of an operating cycle. The Engineering Services Center, Tyndall AFB, Florida, OPR for the Civil Engineering Materiel Acquisition System (CEMAS), said specific demand data is not documented in CEMAS, but may be available from base supply on the Materiel Requirements Listing. The repair cycle in civil engineering is based on whether or not the item can be repaired, and whether or not the item is real property. Real property,

such as building environmental systems receive contractor maintenance where pipeline data is not tracked by the Air Force. Other items such as generators, barriers, and fire equipment may be repaired by Air Force personnel, but use data is not tracked by CEMAS and therefore failures can not be equated to an operating cycle.

## Summary

Mabe and Ormston (1984) conducted some of the first research using actual data from a non-aircraft system in Dyna-METRIC. Based on the results of their research, it appeared that similar applications of the model may be possible for other selected non-aircraft systems. For this report, it was not practical for the authors to collect sample data from a large number of non-aircraft systems to empirically test the feasibility of using Dyna-METRIC for each of these systems. Instead, this report represents an initial investigation into the potential limitations of model assumptions, variable definitions and data availability. This report is intended to identify problems likely to be encountered when and if users attempt to actually assess non-aircraft system performance with the Dyna-METRIC model.

This early part of this chapter summarized a research study by Hearn (1985) that studied the potential applicability of Dyna-METRIC to ICBMs, while the remainder of the chapter addressed potential applications to space-based $C^3$ equipment, as well as transportation and civil engineering equipment. In all cases, the definition of model variables to adequately represent these

different systems seems possible. For electronic components of these systems, the model assumptions appear reasonable, but for much of the mechanical equipment (and logistics support practices), the acceptability of some of Dyna-METRIC's assumptions may be suspect. Probably the greatest hurdle confronting interested users is the availability of data. The redefinition of model variables requires that specific data be available relative to the new variable definitions. In many cases, the data can be derived with much difficulty, but in others, it isn't available at all. Furthermore, before any large-scale routine assessments could be accomplished, data sources need to be automated.

## Chapter V

## Conclusions and Recommendations

### Conclusions

Throughout this report, the authors have focused on adapting the Dyna-METRIC model for assessing non-aircraft systems by redefining three critical variables in terms related to specific non-aircraft weapon systems. Additionally, the critical nature of properly representing redundancy for these systems has been highlighted, and the flexibility within Dyna-METRIC that allows users to model mobility when required was demonstrated. The methodology for studying each of these areas was presented and the results were thoroughly analyzed. The last section of this report presents the conclusions based on the research results and generalizations extended from the results. Specific recommendations are presented for consideration where appropriate.

General. Dyna-METRIC can be successfully used to assess capability and compute recoverable spares requirements for various $C^3$ and CE systems. However, users must first redefine three aircraft-oriented variables in the model for use with non-aircraft systems. These three variables are: demands per flying hour, sorties, and operational unit.

Demands per flying hour is best redefined as demands per operating hour. This is computed by dividing demands generated over a period of time by the total number of operating hours experienced in the same period by all units being assessed. AFLC has proposed a method to evaluate on-time and off-time failures, but has not yet arrived at a verified version of their model.

Sorties are best described in non-aircraft systems as operating cycles of one hour duration. Using this combination of variables, the output from the model for expected sorties at a given point in time can be directly interpreted as expected operating hours.

An operational unit can be defined as either an entire system with all its sub-systems/components rolled into a single "aircraft", or it can be each separate sub-system modeled separately, where the results for the system must be summed from the results for each sub-system. The first method yields a more optimistic assessment, but neither differs by a substantial amount. Therefore, users could apply either.

For redundant systems, the Minimum QPA variable is sensitive enough to have a noticeable impact on unit performance. Users can feel confident that the model will accurately assess the effects of redundant sub-components in a system and report a true picture of the effects. However, the QPA and Minimum QPA must be accurately determined if the results are to be accurate with respect to the true capabilities of the system.

The use of Dyna-METRIC options 10 and 16 provide an additional level of flexibility in varying model input parameters. It can be used to extend the period of analysis or to change variables that normally remain constant throughout a model run.

Dyna-METRIC appears to have sufficient flexibility in its variable specifications and equations to be able to represent the important features of a wide variety of non-aircraft weapon systems and their associated logistics processes. The mathema-

tics of any model require that simplifying assumptions be made, and for electronic components, the assumptions inherent in Dyna-METRIC appear at least as reasonable as they are for aircraft systems. On the other hand, some of the model's assumptions for mechanical components may not be so acceptable. The following sections will briefly discuss the conclusions regarding the feasibility of using Dyna-METRIC for each of the types of non-aircraft systems discussed in this report.

Missile Systems. The modeling of ICBMs parallels the modeling of aircraft units in terms of definition of an operational unit, since multiple airframes are assigned to each base. Dyna-METRIC has been used to model the only system that is continuously operating on the airframe (the guidance system). This research did not study the feasibility of using Dyna-METRIC to model the dormant components on the missile, but the nature of these components (and the model) make it unlikely that it can realistically represent these components.

The necessary data appears to be available, but it must be manually extracted from many sources/locations and processed into a format compatible with Dyna-METRIC. This fact alone will severely restrict the possibility of using the model for routine assessments of ICBM systems. Aside from the limited number of potential components for evaluation and the difficulty in obtaining the necessary data, probably the greatest drawback to using Dyna-METRIC for ICBMs is the nature of the system itself. Current ICBM guidance systems are so reliable (relative to aircraft systems) that there are not enough demands generated to notice-

ably degrade airframe availability, even when evaluated over a long period of time. This limits the useful information the model can provide to aid management in decision making processes. Based on the initial study by Hearn (1985), there appears to be limited benefits to be gained from using Dyna-METRIC for assessing ICBM components.

Space Systems. While the control and user segments of the space environment have the most potential for Dyna-METRIC assessment, the lack of sufficient data in a standard form inhibits the immediate use of the model. The specific operating cycles expressed in terms of on-time, off-time, and stand-by time need to be defined and standardized for all space environment equipment. Until specific, standard procedures are established to gather, format and transmit data to AFLC by the users of space equipment, the possibility of using Dyna-METRIC to evaluate any segment of the space environment remains small.

Transportation and Civil Engineering Equipment. While transportation and civil engineering systems can be successfully defined in terms of the Dyna-METRIC variables, there is not sufficient data available in a usable form to equate demands to an operating cycle for most systems. Dyna-METRIC's focus on pipelines between repair facilities is difficult to represent in situations where repair is done by civilian contractors, and the reparable parts are removed from Air Force accountability and ownership. Finally, the assumption of a Poisson demand rate, and exponential MTBF, for parts in vehicles may not be appropriate.

Although it generally appears Dyna-METRIC has little utility to assess these systems, it is possible some vehicle systems and power generators could be analyzed with Dyna-METRIC if a suitable system to track and store demand data can be devised. Such a system would have to consider an operating cycle, individual parts failure data, and pipelines for contractor repaired parts before they leave Air Force accountability.

## Recommendations

Dyna-METRIC contains current state-of-the-art techniques for assessing the wartime capability (in operational terms) of weapon systems as a function of selected logistics resource groups. Although the model was initially designed to study specific aircraft related support problems, the inherent flexibility in the structure of the model, as well as the similarities among many of represented logistics processes give the model tremendous potential for applications beyond the original design.

The research efforts discussed in this report represent initial efforts of trying to define the scope of applications of the Dyna-METRIC model. The conclusions offered are based on limited experiences and the best data obtainable for the intent of the research. Readers should carefully evaluate our conclusions while fully considering the the constraints that were present. There is plenty of room for additional research, and we have merely taken a first serious look at the <u>potential</u> expanded applications of Dyna-METRIC. With this in mind, we offer some recommendations for the Air Force community to consider.

The Air Force needs to carefully study the merits of computing non-aircraft component requirements based on on-time and off-time failures. AFLC/MMMR's efforts to establish a dual-distribution method is admirable, but their initial proposal yielded undesirable results for a stockage policy. If a technique can be developed and validated against empirical data, and determined to produce better results than current single distribution approaches, then the Air Force will have vital information needed to accept or reject a new approach. The decision must heavily weigh the impact of collecting on-time and off-time failure data on a continuous basis, which will likely require changes to maintenance data collection systems and procedures. Continued research is needed to determine if the potential cost of a dual distribution computations is worth the benefits of the improved accuracy in requirements computations. Until such a technique is developed and accepted, the Air Force should continue to use a simple "demands over time" formula for computing parts requirements for non-aircraft systems.

Further research on specific non-aircraft systems described in this report is needed to substantiate the generalizations based upon the author's empirical research on a single CE system (the mobile TACS). This research should explicitly model specific non-aircraft systems (identified as feasible applications) using actual data wherever possible. Such research will contribute to the increasing knowledge and experience base of Dyna-METRIC usage, and can potentially lead to improved techniques for managing our logistics resources and weapon systems.

Despite the flexibility of Dyna-METRIC as discussed in this report, there are very real limits as to how far the model can be stretched to fit applications that it was not intentionally designed to meet. As we determine the bounds of applicability, Air Force users can then turn their attention toward adapting the best features and logic of Dyna-METRIC into programs that will meet the needs of other specific weapon systems. Some modifications have been already been proposed for the most current version of Dyna-METRIC, where the model is inadequate to meet certain applications; such an example is the need for lateral resupply capability when to model strategic airlift. For other applications, there may only be some basic approaches that can be borrowed from Dyna-METRIC and incorporated into totally new and separate models. Air Force personnel must continue to stretch their creativity and talents to develop better management tools to help maximize the utility of our limited resources.

## Appendix A: Glossary of Acronyms

| | |
|---|---|
| AF | Air Force |
| AFCC | Air Force Communications Command |
| AFIT | Air Force Institute of Technology |
| AFLC | Air Force Logistics Command |
| AFLMC | Air Force Logistics Management Center |
| AGMC | Aerospace Guidance and Metrology Center |
| ALC | Air Logistics Center |
| $C^3$ | Command, Control and Communications |
| CE | Communications-Electronic |
| CIRF | Centralized Intermediate Repair Facility |
| CREATE | Computational Resources for Engineering and Simulation, Training and Education |
| CRP | Control and Reporting Post |
| DØ29 | WRSK/BLSS Requirements Computation System |
| DØ41 | Recoverable Consumption Item Requirements System |
| FACP | Forward Air Control Post |
| FMC | Fully Mission Capable |
| HQ AFLC | Headquarters, Air Force Logistics Command |
| HQ USAF | Headquarters, United States Air Force |
| ICBM | Intercontinental Ballistic Missile |
| ILM | Intermediate Level Maintenance |
| LRU | Line Replaceable Unit |
| MAJCOM | Major Command |
| MD | Mission Design |
| MDS | Mission/Design/Series (Aircraft or Missile) |
| MHE | Material Handling Equipment |

| | |
|---|---|
| MTBD | Mean Time Between Demand |
| MTBF | Mean Time Between Failure |
| NMC | Not Mission Capable (Suffix designates the reason: M-Maintenance, S-Supply, B-both.) |
| NRTS | Not Repairable This Station |
| NSN | National Stock Number |
| OPR | Office of Primary Responsibility |
| OST | Order and Ship Time |
| PMC | Partially Mission Capable (Suffix designates reasons: M-Maintenance, Supply, B-Both) |
| QPA | Quantity Per Aircraft<br>Quantity Per Application<br>Quantity Per Assembly |
| RCT | Repair Cycle Time |
| SRU | Shop Replaceable Unit |
| TAC | Tactical Air Command |
| TAF | Tactical Air Forces |
| TT&C | Tracking, Telemetry and Command |
| USAFE | United States Air Force Europe |
| WRM | War Reserve Material |
| WRSK | War Readiness Spares Kit |
| WWMCCS | World Wide Military Communications and Control System |

Appendix B: Research Data File

```
CE RESEARCH, BASELINE RUN
01.500                VERSION 4.4  MT1MT2MT3MT4MT5
   1   3   5   7  10  15  20  25  30
OPT
      8 70
     11  00.80
     16
     15
DEPT
SAB                                     180.01          180. 180. 180. 0     10.00
CIRF
HOAS                                         1                        0     1.00
BASE
606CHOAS2.0002.0001.00 01.00 3.00                       1.0001.0001.00000.0  1.00    1
609CHOAS1.0001.0001.00 01.00 3.00                       1.0001.0001.00000.0  1.00    1
626FHOAS2.0002.0001.00 01.00 3.00                       1.0001.0001.00000.0  1.00    1
636FHOAS2.0002.0001.00 01.00 3.00                       1.0001.0001.00000.0  1.00    1
619FHOAS1.0001.0001.00 01.00 3.00                       1.0001.0001.00000.0  1.00    1
629FHOAS1.0001.0001.00 01.00 3.00                       1.0001.0001.00000.0  1.00    1
TRNS
HOAS SAB  .250  .250  0 1.0   180.  1.0
606C SAB  2.500 2.500 0 3.0   180.  1.0
609C SAB  1.500 1.500 0 3.0   180.  1.0
626F SAB  2.500 2.500 0 3.0   180.  1.0
636F SAB  2.500 2.500 0 3.0   180.  1.0
619F SAB  1.500 1.500 0 3.0   6.00  1.0
629F SAB  1.500 1.500 0 3.0   180.  1.0
ACFT
606C  0.    1  1.   99  0.
609C  0.    1  1.   99  0.
626F  0.    1  1.   99  0.
636F  0.    1  1.   99  0.
619F  0.    1  1.   99  0.
629F  0.    1  1.   99  0.
```

```
SRTS
606C  0.   10.0     324.0
609C  0.   124.0
626F  0.   10.0     324.0
636F  0.   10.0     424.0
619F  0.   10.0     224.0   60.0     724.0
629F  0.   10.0     224.0
FLHR
606C 0.    1 1.0  99 0.
609C 0.    1 1.0  99 0.
626F 0.    1 1.0  99 0.
636F 0.    1 1.0  99 0.
619F 0.    1 1.0  99 0.
629F 0.    1 1.0  99 0.
ATTR
606C0.      10.      990.
609C0.      10.      990.
626F0.      10.      990.
636F0.      10.      990.
619F0.      10.      990.
629F0.      10.      990.
TURN
606C24.01 990.
609C24.01 990.
626F24.01 990.
636F24.01 990.
619F24.01 990.
629F24.01 990.
LRU
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5895-00-400-8106      1.0       180. 99.0      180. 180. 623.15   TPS43EC 1
5840-00-162-1231 SAB  1 1 01 01 0 .00113        1800 .470 0.00 1800 .470 0.00
5840-00-162-1231      1.0       180. 99.0      180. 180. 53817.50 TPS43EC 1
5960-00-078-0684 SAB  1 1 01 01 0 .00099        3.00 .920 0.00 3.00 .920 0.00
5960-00-078-0684      1.0       180. 99.0      180. 180. 48523.30 TPS43EC 1
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5840-00-572-1617 SAB  1 1 01 01 0 .00090        1200 .190 0.00 1200 .190 0.00
5840-00-572-1617      1.0       180. 99.0      180. 180. 21408.55 TPS43EC 1
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5840-01-035-1166 SAB  1 1 01 01 0 .00209       1.00 .980 0.00 1.00 .980 0.00
5840-01-035-1166      1.0         180. 99.0    180. 180. 3234.20  TPS43EC 1
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5895-00-400-8104      1.0         180. 99.0    180. 180. 516.64   TPS43EC 1
5895-00-400-8108 SAB  1 1 01 01 0 .00036       1000 .460 0.00 1000 .460 0.00
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5840-01-037-5526 SAB  1 1 01 01 0 .00023       1900 .570 0.00 1900 .570 0.00
5840-01-037-5526      1.0         180. 99.0    180. 180. 26079.60 TPS43EC 1
5840-01-055-9558 SAB  1 1 01 01 0 .00083       6.00 0.00 0.00 6.00 0.00 0.00
5840-01-055-9558      1.0         180. 99.0    180. 180. 4381.49  TPS43EC 1
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6130-00-443-6963      1.0         180. 99.0    180. 180. 1158.75  24U-8C  1
6115-00-456-3904 SAB  1 1 06 03 0 .00046       2.00 .950 0.00 2.00 .950 0.00
6115-00-456-3904      1.0         180. 99.0    180. 180. 14028.60 24U-8C  1
6110-00-442-7513 SAB  1 1 06 03 0 .00055       8.00 .620 0.00 8.00 .620 0.00
6110-00-442-7513      1.0         180. 99.0    180. 180. 1446.00  24U-8C  1
6110-00-442-7488 SAB  1 1 06 03 0 .00066       1200 .310 .308 1200 .310 .308
6110-00-442-7488      1.0         180. 99.0    180. 180. 752.62   24U-8C  1
6110-00-442-7478 SAB  1 1 06 03 0 .00034       9.00 .160 .164 9.00 .160 .164
6110-00-442-7478      1.0         180. 99.0    180. 180. 165.02   24U-8C  1
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2910-00-109-2539      1.0         180. 99.0    180. 180. 357.50   24U-8C  1
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5820-00-921-6562      1.0         180. 99.0    180. 180. 1462.00  TRC-97  1
5820-00-921-6565 SAB  1 1 08 02 0 .00203       1700 .230 0.00 1700 .230 0.00
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5820-00-921-6566      1.0         180. 99.0    180. 180. 600.60   TRC-97  1
5820-00-921-6569 SAB  1 1 08 02 0 .00030       1400 .620 0.00 1400 .620 0.00
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5820-00-921-6570       1.0        180. 99.0       180. 180. 251.47   TRC-97  1
5820-00-921-6571 SAB   1 1 08 02  0 .00008         1100 0.00 0.00 1100 0.00 0.00
5820-00-921-6571       1.0        180. 99.0       180. 180. 334.75   TRC-97  1
5820-00-921-6574 SAB   1 1 08 02  0 .00032         1400 .320 0.00 1400 .320 0.00
5820-00-921-6574       1.0        180. 99.0       180. 180. 888.90   TRC-97  1
5820-00-921-6696 SAB   1 1 08 02  0 .00020         8.00 .170 0.00 8.00 .170 0.00
5820-00-921-6696       1.0        180. 99.0       180. 180. 754.00   TRC-97  1
5820-00-123-3954 SAB   1 1 06 02  0 .00033         1200 .600 0.00 1200 .600 0.00
5820-00-123-3954       1.0        180. 99.0       180. 180. 1903.00  TRC-87C 1
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5820-00-485-8881       1.0        180. 99.0       180. 180. 68.31    TRC-87C 1
5820-00-401-8061 SAB   1 1 09 03  0 .00043         1300 .470 0.00 1300 .470 0.00
5820-00-401-8061       1.0        180. 99.0       180. 180. 417.20   TRC-87  1
5820-00-416-8546 SAB   1 1 09 03  0 .00016         0.00 1.00 0.00 0.00 1.00 0.00
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5820-00-416-8552 SAB   1 1 09 03  0 .00008         9.00 .670 0.00 9.00 .670 0.00
5820-00-416-8552       1.0        180. 99.0       180. 180. 216.30   TRC-87  1
5820-00-427-9429 SAB   1 1 09 03  0 .00008         0.00 1.00 0.00 0.00 1.00 0.00
5820-00-427-9429       1.0        180. 99.0       180. 180. 1256.60  TRC-87  1
5820-00-437-9952 SAB   1 1 06 02  0 .00004         1.00 .500 0.00 1.00 .500 0.00
5820-00-437-9952       1.0        180. 99.0       180. 180. 303.90   TRC-87  1
5820-00-491-4046 SAB   1 1 09 03  0 .00027         2.00 .310 0.00 2.00 .310 0.00
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5820-00-494-8815       1.0        180. 99.0       180. 180. 180.25   TRC-87  1
5815-00-050-0230 SAB   1 1 01 01  0 .00095         4.00 0.00 0.00 4.00 0.00 0.00
5815-00-050-0230       1.0        180. 99.0       180. 180. 402.78   TGC-28C 1
5815-00-028-4324 SAB   1 1 01 01  0 .00016         1500 0.00 0.00 1500 0.00 0.00
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5815-00-489-6641 SAB   1 1 01 01  0 .00010         4.00 .330 0.00 4.00 .330 0.00
5815-00-489-6641       1.0        180. 99.0       180. 180. 1531.00  TGC-28C 1
5815-00-140-8604 SAB   1 1 01 01  0 .00008         8.00 0.00 0.00 8.00 0.00 0.00
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5815-00-489-6642       1.0        180. 99.0       180. 180. 1531.00  TGC-28  1
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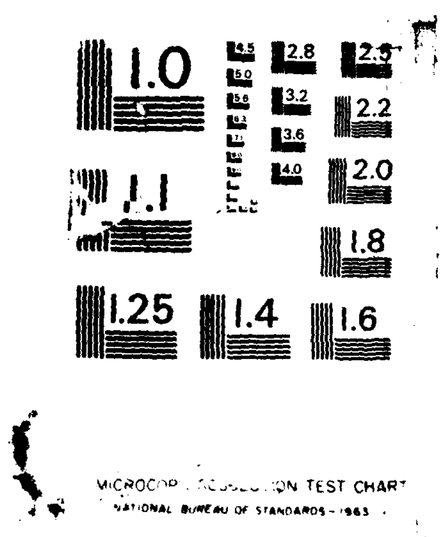
AD-A172 524 ADAPTING DYNA-METRIC TO ASSESS NON-AIRCRAFT SYSTEMS(U) 2/2
AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL
OF SYSTEMS AND LOGISTICS M J BUDDE ET AL MAY 86
UNCLASSIFIED AU/AFIT/LSM-86-1 F/G 15/5 NL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5.6
2.8
3.2
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2.0
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1.25
1.4
1.6
NATIONAL BUREAU OF STANDARDS-1963

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5895-00-450-8365 SAB  1 1 01 01 0 .00008        5.00 0.00 0.00 5.00 0.00 0.00
5895-00-450-8365      1.0         180. 99.0    180. 180. 350.00   TGC-28  1
5895-00-450-8366 SAB  1 1 01 01 0 .00023        4.00 0.00 0.00 4.00 0.00 0.00
5895-00-450-8366      1.0         180. 99.0    180. 180. 1462.00  TGC-28  1
5805-00-466-3086 SAB  1 1 01 01 0 .00004        1.00 0.00 0.00 1.00 0.00 0.00
5805-00-466-3086      1.0         180. 99.0    180. 180. 836.70   TGC-28  1
5805-00-488-4610 SAB  1 1 01 01 0 .00016        1500 0.00 0.00 1500 0.00 0.00
5805-00-488-4610      1.0         180. 99.0    180. 180. 1383.00  TGC-28  1
5814-01-114-6703 SAB  1 1 01 01 0 .00004        1400 0.00 0.00 1400 0.00 0.00
5814-01-114-6703      1.0         180. 99.0    180. 180. 1937.43  TGC-28  1
5805-00-999-5032 SAB  1 1 01 01 0 .00021        9.00 .200 0.00 9.00 .200 0.00
5805-00-999-5032      1.0         180. 99.0    180. 180. 80.40    TSC-53C 1
5820-00-167-7673 SAB  1 1 01 01 0 .00012        0.00 1.00 0.00 0.00 1.00 0.00
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5820-00-167-7675 SAB  1 1 01 01 0 .00016        8.00 .500 0.00 8.00 .500 0.00
5820-00-167-7675      1.0         180. 99.0    180. 180. 1930.00  TSC-53  1
5820-00-226-5367 SAB  1 1 01 01 0 .00008        0.00 0.00 1.00 0.00 0.00 1.00
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5820-00-226-5368 SAB  1 1 01 01 0 .00008        0.00 1.00 0.00 0.00 1.00 0.00
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5820-00-226-5436 SAB  1 1 01 01 0 .00004        0.00 1.00 0.00 0.00 1.00 0.00
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5821-00-138-7991 SAB  1 1 01 01 0 .00016        1.00 0.00 0.00 1.00 0.00 0.00
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5821-00-570-4232 SAB  1 1 01 01 0 .00033        3.00 .800 0.00 3.00 .800 0.00
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5821-00-576-4866 SAB  1 1 01 01 0 .00046        1300 .790 0.00 1300 .790 0.00
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5945-00-991-8258 SAB  1 1 15 03 0 .00111        0.00 0.00 1.00 0.00 0.00 1.00
5945-00-991-8258      1.0         180. 99.0    180. 180. 70.21    TSC-60C 1
3030-00-482-8284 SAB  1 1 05 01 0 .00014        0.00 0.00 1.00 0.00 0.00 1.00
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5820-00-005-1867 SAB  1 1 05 01 0 .00008        9.00 0.00 0.00 9.00 0.00 0.00
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5820-00-005-8628 SAB  1 1 05 01 0 .00033        1.00 .700 0.00 1.00 .700 0.00
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5820-00-006-1122 SAB  1 1 05 01 0 .00002        1.00 0.00 0.00 1.00 0.00 0.00
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5820-00-006-1122       1.0        180. 99.0      180. 180. 6521.96  TSC-60  1
5820-00-006-1123 SAB   1 1 05 01 0 .00002         0.00 1.00 0.00 0.00 1.00 0.00
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5820-00-260-0412 SAB   1 1 05 01 0 .00008         0.00 1.00 0.00 0.00 1.00 0.00
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5820-00-409-2470 SAB   1 1 05 01 0 .00040         8.00 .630 0.00 8.00 .630 0.00
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5820-00-492-9774 SAB   1 1 05 01 0 .00013         1100 .630 0.00 1100 .630 0.00
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5840-00-162-1231 606C1.0   609C1.0   626F1.0   636F1.0   619F1.0   629F1.0
5960-00-078-0684 606C1.0   609C1.0   626F1.0   636F1.0   619F1.0   629F1.0
5840-00-396-1208 606C1.0   609C1.0   626F1.0   636F1.0   619F1.0   629F1.0
5840-00-572-1617 606C1.0   609C1.0   626F1.0   636F1.0   619F1.0   629F1.0
5840-01-027-0315 606C1.0   609C1.0   626F1.0   636F1.0   619F1.0   629F1.0
5840-01-034-4607 606C1.0   609C1.0   626F1.0   636F1.0   619F1.0   629F1.0
5840-01-035-1166 606C1.0   609C1.0   626F1.0   636F1.0   619F1.0   629F1.0
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5820-00-921-6562 606C1.0   609C1.0   626F1.0   636F1.0   619F1.0   629F1.0
5820-00-921-6565 606C1.0   609C1.0   626F1.0   636F1.0   619F1.0   629F1.0
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| 5820-00-485-8881 | 606C1.0 | 609C1.0 | 626F0.0 | 636F0.0 | 619F0.0 | 629F0.0 |
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5820-00-006-1122 1 1.0       1.0       11111
5820-00-006-1123 1 1.0       1.0       11111
5820-00-260-0412 1 1.0       1.0       11111
5820-00-409-2470 1 1.0       1.0       11111
5820-00-492-9770 1 1.0       1.0       11111
5820-00-492-9774 1 1.0       1.0       11111
STK
5895-00-400-8106 606C    1 609C    1 626F    1 636F    1 619F    1 629F    1
5895-00-400-8106 SAB     1 HOAS    1
```

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5840-00-162-1231 | 606C | 1 | 609C | 1 | 626F | 1 | 636F | 1 | 619F | 1 | 629F | 1 |
| 5840-00-162-1231 | SAB | 1 | HOAS | 1 | | | | | | | | |
| 5960-00-078-0684 | 606C | 1 | 609C | 1 | 626F | 1 | 636F | 1 | 619F | 1 | 629F | 1 |
| 5960-00-078-0684 | SAB | 2 | HOAS | 1 | | | | | | | | |
| 5840-00-396-1208 | 606C | 1 | 609C | 1 | 626F | 1 | 636F | 1 | 619F | 1 | 629F | 1 |
| 5840-00-396-1208 | SAB | 2 | HOAS | 1 | | | | | | | | |
| 5840-00-572-1617 | 606C | 1 | 609C | 1 | 626F | 1 | 636F | 1 | 619F | 1 | 629F | 1 |
| 5840-00-572-1617 | SAB | 1 | HOAS | 1 | | | | | | | | |
| 5840-01-027-0315 | 606C | 1 | 609C | 1 | 626F | 1 | 636F | 1 | 619F | 1 | 629F | 1 |
| 5840-01-027-0315 | SAB | 1 | HOAS | 1 | | | | | | | | |
| 5840-01-034-4607 | 606C | 1 | 609C | 1 | 626F | 1 | 636F | 1 | 619F | 1 | 629F | 1 |
| 5840-01-034-4607 | SAB | 1 | HOAS | 1 | | | | | | | | |
| 5840-01-035-1166 | 606C | 1 | 609C | 1 | 626F | 1 | 636F | 1 | 619F | 1 | 629F | 1 |
| 5840-01-035-1166 | SAB | 2 | HOAS | 1 | | | | | | | | |
| 5895-00-400-8104 | 606C | 1 | 609C | 1 | 626F | 1 | 636F | 1 | 619F | 1 | 629F | 1 |
| 5895-00-400-8104 | SAB | 1 | HOAS | 1 | | | | | | | | |
| 5895-00-400-8108 | 606C | 1 | 609C | 1 | 626F | 1 | 636F | 1 | 619F | 1 | 629F | 1 |
| 5895-00-400-8108 | SAB | 1 | HOAS | 1 | | | | | | | | |
| 5840-01-037-5526 | 606C | 1 | 609C | 1 | 626F | 0 | 636F | 0 | 619F | 0 | 629F | 0 |
| 5840-01-037-5526 | SAB | 1 | HOAS | 1 | | | | | | | | |
| 5840-01-055-9558 | 606C | 1 | 609C | 1 | 626F | 1 | 636F | 1 | 619F | 1 | 629F | 1 |
| 5840-01-055-9558 | SAB | 1 | HOAS | 1 | | | | | | | | |
| 6130-00-443-6963 | 606C | 4 | 609C | 4 | 626F | 3 | 636F | 3 | 619F | 3 | 629F | 3 |
| 6130-00-443-6963 | SAB | 2 | HOAS | 1 | | | | | | | | |
| 6115-00-456-3904 | 606C | 4 | 609C | 4 | 626F | 3 | 636F | 3 | 619F | 3 | 629F | 3 |
| 6115-00-456-3904 | SAB | 1 | HOAS | 1 | | | | | | | | |
| 6110-00-442-7513 | 606C | 4 | 609C | 4 | 626F | 4 | 636F | 4 | 619F | 4 | 629F | 4 |
| 6110-00-442-7513 | SAB | 1 | HOAS | 1 | | | | | | | | |
| 6110-00-442-7488 | 606C | 4 | 609C | 4 | 626F | 4 | 636F | 4 | 619F | 4 | 629F | 4 |
| 6110-00-442-7488 | SAB | 1 | HOAS | 1 | | | | | | | | |
| 6110-00-442-7478 | 606C | 5 | 609C | 5 | 626F | 4 | 636F | 4 | 619F | 4 | 629F | 4 |
| 6110-00-442-7478 | SAB | 2 | HOAS | 2 | | | | | | | | |
| 2910-00-109-2539 | 606C | 5 | 609C | 5 | 626F | 4 | 636F | 4 | 619F | 4 | 629F | 4 |
| 2910-00-109-2539 | SAB | 2 | HOAS | 2 | | | | | | | | |
| 6110-00-442-7469 | 606C | 4 | 609C | 4 | 626F | 4 | 636F | 4 | 619F | 4 | 629F | 4 |
| 6110-00-442-7469 | SAB | 1 | HOAS | 1 | | | | | | | | |
| 6110-00-442-7477 | 606C | 5 | 609C | 5 | 626F | 4 | 636F | 4 | 619F | 4 | 629F | 4 |
| 6110-00-442-7477 | SAB | 2 | HOAS | 2 | | | | | | | | |
| 5820-00-917-6578 | 606C | 2 | 609C | 2 | 626F | 2 | 636F | 2 | 619F | 2 | 629F | 2 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5820-00-917-6578 | SAB | 1 | HOAS | 1 | | | | | | | | |
| 5820-00-917-8303 | 606C | 2 | 609C | 2 | 626F | 2 | 636F | 2 | 619F | 2 | 629F | 2 |
| 5820-00-917-8303 | SAB | 1 | HOAS | 1 | | | | | | | | |
| 5820-00-921-6562 | 606C | 2 | 609C | 2 | 626F | 2 | 636F | 2 | 619F | 2 | 629F | 2 |
| 5820-00-921-6562 | SAB | 1 | HOAS | 1 | | | | | | | | |
| 5820-00-921-6565 | 606C | 2 | 609C | 2 | 626F | 2 | 636F | 2 | 619F | 2 | 629F | 2 |
| 5820-00-921-6565 | SAB | 1 | HOAS | 1 | | | | | | | | |
| 5820-00-921-6566 | 606C | 2 | 609C | 2 | 626F | 2 | 636F | 2 | 619F | 2 | 629F | 2 |
| 5820-00-921-6566 | SAB | 1 | HOAS | 1 | | | | | | | | |
| 5820-00-921-6569 | 606C | 2 | 609C | 2 | 626F | 2 | 636F | 2 | 619F | 2 | 629F | 2 |
| 5820-00-921-6569 | SAB | 1 | HOAS | 1 | | | | | | | | |
| 5820-00-921-6570 | 606C | 2 | 609C | 2 | 626F | 2 | 636F | 2 | 619F | 2 | 629F | 2 |
| 5820-00-921-6570 | SAB | 1 | HOAS | 1 | | | | | | | | |
| 5820-00-921-6571 | 606C | 2 | 609C | 2 | 626F | 2 | 636F | 2 | 619F | 2 | 629F | 2 |
| 5820-00-921-6571 | SAB | 1 | HOAS | 1 | | | | | | | | |
| 5820-00-921-6574 | 606C | 2 | 609C | 2 | 626F | 2 | 636F | 2 | 619F | 2 | 629F | 2 |
| 5820-00-921-6574 | SAB | 1 | HOAS | 1 | | | | | | | | |
| 5820-00-921-6696 | 606C | 2 | 609C | 2 | 626F | 2 | 636F | 2 | 619F | 2 | 629F | 2 |
| 5820-00-921-6696 | SAB | 1 | HOAS | 1 | | | | | | | | |
| 5820-00-123-3954 | 606C | 2 | 609C | 2 | SAB | 2 | HOAS | 2 | | | | |
| 5820-00-252-2759 | 606C | 2 | 609C | 2 | SAB | 2 | HOAS | 2 | | | | |
| 5820-00-485-8881 | 606C | 2 | 609C | 2 | SAB | 2 | HOAS | 2 | | | | |
| 5820-00-401-8061 | 606C | 2 | 609C | 2 | SAB | 2 | HOAS | 2 | | | | |
| 5820-00-416-8546 | 606C | 2 | 609C | 2 | SAB | 2 | HOAS | 2 | | | | |
| 5820-00-416-8552 | 606C | 2 | 609C | 2 | SAB | 2 | HOAS | 2 | | | | |
| 5820-00-427-9429 | 606C | 2 | 609C | 2 | SAB | 2 | HOAS | 2 | | | | |
| 5820-00-437-9952 | 606C | 2 | 609C | 2 | SAB | 2 | HOAS | 2 | | | | |
| 5820-00-491-4046 | 606C | 2 | 609C | 2 | SAB | 2 | HOAS | 2 | | | | |
| 5820-00-494-8815 | 606C | 2 | 609C | 2 | SAB | 2 | HOAS | 2 | | | | |
| 5815-00-050-0230 | 606C | 2 | 609C | 2 | SAB | 1 | HOAS | 1 | | | | |
| 5815-00-028-4324 | 606C | 2 | 609C | 2 | SAB | 1 | HOAS | 1 | | | | |
| 5815-00-489-6641 | 606C | 2 | 609C | 2 | SAB | 1 | HOAS | 1 | | | | |
| 5815-00-140-8604 | 606C | 2 | 609C | 2 | SAB | 1 | HOAS | 1 | | | | |
| 5815-00-489-6642 | 606C | 2 | 609C | 2 | SAB | 1 | HOAS | 1 | | | | |
| 5895-00-450-8365 | 606C | 2 | 609C | 2 | SAB | 1 | HOAS | 1 | | | | |
| 5895-00-450-8366 | 606C | 2 | 609C | 2 | SAB | 1 | HOAS | 1 | | | | |
| 5805-00-466-3086 | 606C | 2 | 609C | 2 | SAB | 1 | HOAS | 1 | | | | |
| 5805-00-488-4610 | 606C | 2 | 609C | 2 | SAB | 1 | HOAS | 1 | | | | |
| 5814-01-114-6703 | 606C | 2 | 609C | 2 | SAB | 1 | HOAS | 1 | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5805-00-999-5032 | SAB | 1 | HOAS | 1 | 626F | 2 | 636F | 2 | 619F | 2 | 629F | 2 |
| 5820-00-167-7673 | SAB | 1 | HOAS | 1 | 626F | 2 | 636F | 2 | 619F | 2 | 629F | 2 |
| 5820-00-167-7675 | SAB | 1 | HOAS | 1 | 626F | 2 | 636F | 2 | 619F | 2 | 629F | 2 |
| 5820-00-226-5367 | SAB | 1 | HOAS | 1 | 626F | 2 | 636F | 2 | 619F | 2 | 629F | 2 |
| 5820-00-226-5368 | SAB | 1 | HOAS | 1 | 626F | 2 | 636F | 2 | 619F | 2 | 629F | 2 |
| 5820-00-226-5436 | SAB | 1 | HOAS | 1 | 626F | 2 | 636F | 2 | 619F | 2 | 629F | 2 |
| 5820-00-924-8465 | SAB | 1 | HOAS | 1 | 626F | 2 | 636F | 2 | 619F | 2 | 629F | 2 |
| 5821-00-138-7991 | SAB | 1 | HOAS | 1 | 626F | 2 | 636F | 2 | 619F | 2 | 629F | 2 |
| 5821-00-570-4232 | SAB | 1 | HOAS | 1 | 626F | 2 | 636F | 2 | 619F | 2 | 629F | 2 |
| 5821-00-576-4866 | SAB | 1 | HOAS | 1 | 626F | 2 | 636F | 2 | 619F | 2 | 629F | 2 |
| 5945-00-991-8258 | 606C | 10 | 609C | 10 | SAB | 2 | HOAS | 2 | | | | |
| 3030-00-482-8284 | 606C | 5 | 609C | 5 | SAB | 1 | HOAS | 1 | | | | |
| 5820-00-005-1867 | 606C | 2 | 609C | 2 | SAB | 1 | HOAS | 1 | | | | |
| 5820-00-005-8628 | 606C | 2 | 609C | 2 | SAB | 1 | HOAS | 1 | | | | |
| 5820-00-006-1122 | 606C | 2 | 609C | 2 | SAB | 1 | HOAS | 1 | | | | |
| 5820-00-006-1123 | 606C | 2 | 609C | 2 | SAB | 1 | HOAS | 1 | | | | |
| 5820-00-260-0412 | 606C | 2 | 609C | 2 | SAB | 1 | HOAS | 1 | | | | |
| 5820-00-409-2470 | 606C | 2 | 609C | 2 | SAB | 1 | HOAS | 1 | | | | |
| 5820-00-492-9770 | 606C | 2 | 609C | 2 | SAB | 1 | HOAS | 1 | | | | |
| 5820-00-492-9774 | 606C | 2 | 609C | 2 | SAB | 1 | HOAS | 1 | | | | |

## Appendix C: Results of AFLC/MMMR Proposed Formulas

### Explanation of Input Data columns:

- Item is the last four of the NSN
- Total Fail is the total failures of the part in 18 months from the Sembach data
- % NOP Fail and % OP Fail are scaled percentages of the Total Failures in complimentary ratios
- # NOP Fail = Fnon-op from the MMMR formulas
- # OP Fail = Fop from the MMMR formulas
- Program Months = P from the MMMR formulas
- One Day Program = ODP from the MMMR formulas
- Number of Units = number of units supported from the MMMR formulas

### Explanation of the Comparison Data columns:

- Peacetime Duty Cycle = Dp from the MMMR formulas
- Ops Fail Rate = FRops from the MMMR formulas
- Non-Ops Fail Rate = FRnon-op from the MMMR formulas
- Requiremnt = Requirement from the MMMR formulas
- Total Fail Rate = FRops + FRnon-op (Note: this value assumes the mean of the total failure distribution is the sum of the two independent failure distributions. It was not used in any calculations, and is reported here for information only!)
- Standard Fail Rate is my computed failure rate, and is shown here for comparison
- Current Requiremnt is the authorized WRSK level as of 8 June 1984

### Explanation of the Layout:

Each NSN is listed and computations completed for 8 variations in the % NOP Fail/% OP Fail ratio. By blocking all the data for each NSN in this fashion, the immediate trends in results for each NSN can be seen without cross-referencing to another part of the Comparison Data sheet.

INPUT DATA (PART ONE)

| Item | Total Fail | % NOP Fail | % OP Fail | # NOP Fail | # OP Fail | Program months | One Day Program | Months of Months |
|---|---|---|---|---|---|---|---|---|
| 9176 | 1 | 0.00 | 1.00 | 0.00 | 1.00 | 216 | 96 | 12 |
| | 1 | 0.02 | 0.98 | 0.02 | 0.98 | 216 | 96 | 12 |
| | 1 | 0.05 | 0.95 | 0.05 | 0.95 | 216 | 96 | 12 |
| | 1 | 0.10 | 0.90 | 0.10 | 0.90 | 216 | 96 | 12 |
| | 1 | 0.25 | 0.75 | 0.25 | 0.75 | 216 | 96 | 12 |
| | 1 | 0.50 | 0.50 | 0.50 | 0.50 | 216 | 96 | 12 |
| | 1 | 0.75 | 0.25 | 0.75 | 0.25 | 216 | 96 | 12 |
| | 1 | 1.00 | 0.00 | 1.00 | 0.00 | 216 | 96 | 12 |
| 1231 | 34 | 0.00 | 1.00 | 0.00 | 34.00 | 216 | 96 | 12 |
| | 34 | 0.02 | 0.98 | 0.68 | 33.32 | 216 | 96 | 12 |
| | 34 | 0.05 | 0.95 | 1.70 | 32.30 | 216 | 96 | 12 |
| | 34 | 0.10 | 0.90 | 3.40 | 30.60 | 216 | 96 | 12 |
| | 34 | 0.25 | 0.75 | 8.50 | 25.50 | 216 | 96 | 12 |
| | 34 | 0.50 | 0.50 | 17.00 | 17.00 | 216 | 96 | 12 |
| | 34 | 0.75 | 0.25 | 25.50 | 8.50 | 216 | 96 | 12 |
| | 34 | 1.00 | 0.00 | 34.00 | 0.00 | 216 | 96 | 12 |
| [illegible] | 24 | 0.00 | 1.00 | 0.00 | 24.00 | 216 | 96 | 12 |
| | 24 | 0.02 | 0.98 | 0.48 | 23.52 | 216 | 96 | 12 |
| | 24 | 0.05 | 0.95 | 1.20 | 22.80 | 216 | 96 | 12 |
| | 24 | 0.10 | 0.90 | 2.40 | 21.60 | 216 | 96 | 12 |
| | 24 | 0.25 | 0.75 | 6.00 | 18.00 | 216 | 96 | 12 |
| | 24 | 0.50 | 0.50 | 12.00 | 12.00 | 216 | 96 | 12 |
| | 24 | 0.75 | 0.25 | 18.00 | 6.00 | 216 | 96 | 12 |
| | 24 | 1.00 | 0.00 | 24.00 | 0.00 | 216 | 96 | 12 |
| 1209 | 37 | 0.00 | 1.00 | 0.00 | 37.00 | 216 | 96 | 12 |
| | 37 | 0.02 | 0.98 | 0.74 | 36.26 | 216 | 96 | 12 |
| | 37 | 0.05 | 0.95 | 1.85 | 35.15 | 216 | 96 | 12 |
| | 37 | 0.10 | 0.90 | 3.70 | 33.30 | 216 | 96 | 12 |
| | 37 | 0.25 | 0.75 | 9.25 | 27.75 | 216 | 96 | 12 |
| | 37 | 0.50 | 0.50 | 18.50 | 18.50 | 216 | 96 | 12 |
| | 37 | 0.75 | 0.25 | 27.75 | 9.25 | 216 | 96 | 12 |
| | 37 | 1.00 | 0.00 | 37.00 | 0.00 | 216 | 96 | 12 |
| 1617 | 20 | 0.00 | 1.00 | 0.00 | 20.00 | 216 | 96 | 12 |
| | 20 | 0.02 | 0.98 | 0.40 | 19.60 | 216 | 96 | 12 |
| | 20 | 0.05 | 0.95 | 1.00 | 19.00 | 216 | 96 | 12 |
| | 20 | 0.10 | 0.90 | 2.00 | 18.00 | 216 | 96 | 12 |
| | 20 | 0.25 | 0.75 | 5.00 | 15.00 | 216 | 96 | 12 |
| | 20 | 0.50 | 0.50 | 10.00 | 10.00 | 216 | 96 | 12 |
| | 20 | 0.75 | 0.25 | 15.00 | 5.00 | 216 | 96 | 12 |
| | 20 | 1.00 | 0.00 | 20.00 | 0.00 | 216 | 96 | 12 |
| 0915 | 20 | 0.00 | 1.00 | 0.00 | 20.00 | 216 | 96 | 12 |
| | 20 | 0.02 | 0.98 | 0.40 | 19.60 | 216 | 96 | 12 |
| | 20 | 0.05 | 0.95 | 1.00 | 19.00 | 216 | 96 | 12 |
| | 20 | 0.10 | 0.90 | 2.00 | 18.00 | 216 | 96 | 12 |
| | 20 | 0.25 | 0.75 | 5.00 | 15.00 | 216 | 96 | 12 |
| | 20 | 0.50 | 0.50 | 10.00 | 10.00 | 216 | 96 | 12 |
| | 20 | 0.75 | 0.25 | 15.00 | 5.00 | 216 | 96 | 12 |
| | 20 | 1.00 | 0.00 | 20.00 | 0.00 | 216 | 96 | 12 |

INPUT DATA (PART TWO)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 9607 | 5 | 0.00 | 1.00 | 0.00 | 5.00 | 216 | 96 | 12 |
| | 5 | 0.02 | 0.98 | 0.10 | 4.90 | 216 | 96 | 12 |
| | 5 | 0.05 | 0.95 | 0.25 | 4.75 | 216 | 96 | 12 |
| | 5 | 0.10 | 0.90 | 0.50 | 4.50 | 216 | 96 | 12 |
| | 5 | 0.25 | 0.75 | 1.25 | 3.75 | 216 | 96 | 12 |
| | 5 | 0.50 | 0.50 | 2.50 | 2.50 | 216 | 96 | 12 |
| | 5 | 0.75 | 0.25 | 3.75 | 1.25 | 216 | 96 | 12 |
| | 5 | 1.00 | 0.00 | 5.00 | 0.00 | 216 | 96 | 12 |
| 1166 | 63 | 0.00 | 1.00 | 0.00 | 63.00 | 216 | 96 | 12 |
| | 63 | 0.02 | 0.98 | 1.26 | 61.74 | 216 | 96 | 12 |
| | 63 | 0.05 | 0.95 | 3.15 | 59.85 | 216 | 96 | 12 |
| | 63 | 0.10 | 0.90 | 6.30 | 56.70 | 216 | 96 | 12 |
| | 63 | 0.25 | 0.75 | 15.75 | 47.25 | 216 | 96 | 12 |
| | 63 | 0.50 | 0.50 | 31.50 | 31.50 | 216 | 96 | 12 |
| | 63 | 0.75 | 0.25 | 47.25 | 15.75 | 216 | 96 | 12 |
| | 63 | 1.00 | 0.00 | 63.00 | 0.00 | 216 | 96 | 12 |
| 3104 | 8 | 0.00 | 1.00 | 0.00 | 8.00 | 216 | 96 | 12 |
| | 8 | 0.02 | 0.98 | 0.16 | 7.84 | 216 | 96 | 12 |
| | 8 | 0.05 | 0.95 | 0.40 | 7.60 | 216 | 96 | 12 |
| | 8 | 0.10 | 0.90 | 0.80 | 7.20 | 216 | 96 | 12 |
| | 8 | 0.25 | 0.75 | 2.00 | 6.00 | 216 | 96 | 12 |
| | 8 | 0.50 | 0.50 | 4.00 | 4.00 | 216 | 96 | 12 |
| | 8 | 0.75 | 0.25 | 6.00 | 2.00 | 216 | 96 | 12 |
| | 8 | 1.00 | 0.00 | 8.00 | 0.00 | 216 | 96 | 12 |
| 6101 | 11 | 0.00 | 1.00 | 0.00 | 11.00 | 216 | 96 | 12 |
| | 11 | 0.02 | 0.98 | 0.22 | 10.78 | 216 | 96 | 12 |
| | 11 | 0.05 | 0.95 | 0.55 | 10.45 | 216 | 96 | 12 |
| | 11 | 0.10 | 0.90 | 1.10 | 9.90 | 216 | 96 | 12 |
| | 11 | 0.25 | 0.75 | 2.75 | 8.25 | 216 | 96 | 12 |
| | 11 | 0.50 | 0.50 | 5.50 | 5.50 | 216 | 96 | 12 |
| | 11 | 0.75 | 0.25 | 8.25 | 2.75 | 216 | 96 | 12 |
| | 11 | 1.00 | 0.00 | 11.00 | 0.00 | 216 | 96 | 12 |
| 5526 | 7 | 0.00 | 1.00 | 0.00 | 7.00 | 216 | 96 | 12 |
| | 7 | 0.02 | 0.98 | 0.14 | 6.86 | 216 | 96 | 12 |
| | 7 | 0.05 | 0.95 | 0.35 | 6.65 | 216 | 96 | 12 |
| | 7 | 0.10 | 0.90 | 0.70 | 6.30 | 216 | 96 | 12 |
| | 7 | 0.25 | 0.75 | 1.75 | 5.25 | 216 | 96 | 12 |
| | 7 | 0.50 | 0.50 | 3.50 | 3.50 | 216 | 96 | 12 |
| | 7 | 0.75 | 0.25 | 5.25 | 1.75 | 216 | 96 | 12 |
| | 7 | 1.00 | 0.00 | 7.00 | 0.00 | 216 | 96 | 12 |
| 5553 | 20 | 0.00 | 1.00 | 0.00 | 20.00 | 216 | 96 | 12 |
| | 20 | 0.02 | 0.98 | 0.40 | 19.60 | 216 | 96 | 12 |
| | 20 | 0.05 | 0.95 | 1.00 | 19.00 | 216 | 96 | 12 |
| | 20 | 0.10 | 0.90 | 2.00 | 18.00 | 216 | 96 | 12 |
| | 20 | 0.25 | 0.75 | 5.00 | 15.00 | 216 | 96 | 12 |
| | 20 | 0.50 | 0.50 | 10.00 | 10.00 | 216 | 96 | 12 |
| | 20 | 0.75 | 0.25 | 15.00 | 5.00 | 216 | 96 | 12 |
| | 20 | 1.00 | 0.00 | 20.00 | 0.00 | 216 | 96 | 12 |

COMPARISON DATA PART ONE

| Item | Fraction Time Cycle | Ops Fail Rate | Non-Ops Fail Rate | Daily Use Program | Requirement | Total Fail Rate | Standard Fail Rate | Current Requirement |
|---|---|---|---|---|---|---|---|---|
| 5176 | 0.3333333 | 0.0000192 | 0.0000000 | 600 | 0.01 | 0.0000193 | 0.0000276 | 1 |
| | 0.3333333 | 0.0000189 | 0.0000002 | 600 | 0.01 | 0.0000191 | | |
| | 0.3333333 | 0.0000193 | 0.0000005 | 600 | 0.01 | 0.0000198 | | |
| | 0.3333333 | 0.0000174 | 0.0000010 | 600 | 0.01 | 0.0000183 | | |
| | 0.3333333 | 0.0000145 | 0.0000024 | 600 | 0.01 | 0.0000169 | | |
| | 0.3333333 | 0.0000096 | 0.0000048 | 600 | 0.00 | 0.0000145 | | |
| | 0.3333333 | 0.0000048 | 0.0000072 | 600 | -0.00 | 0.0000121 | | |
| | 0.3333333 | 0.0000000 | 0.0000096 | 600 | -0.01 | 0.0000096 | | |
| 1221 | 0.3333333 | 0.0006559 | 0.0000000 | 600 | 0.39 | 0.0006559 | 0.0009394 | 1 |
| | 0.3333333 | 0.0006427 | 0.0000066 | 600 | 0.38 | 0.0006493 | | |
| | 0.3333333 | 0.0006231 | 0.0000164 | 600 | 0.36 | 0.0006395 | | |
| | 0.3333333 | 0.0005903 | 0.0000328 | 600 | 0.34 | 0.0006231 | | |
| | 0.3333333 | 0.0004919 | 0.0000820 | 600 | 0.25 | 0.0005739 | | |
| | 0.3333333 | 0.0003279 | 0.0001640 | 600 | 0.10 | 0.0004919 | | |
| | 0.3333333 | 0.0001640 | 0.0002459 | 600 | -0.04 | 0.0004099 | | |
| | 0.3333333 | 0.0000000 | 0.0003279 | 600 | -0.19 | 0.0003279 | | |
| 0534 | 0.3333333 | 0.0004630 | 0.0000000 | 600 | 0.28 | 0.0004630 | 0.0006631 | 1 |
| | 0.3333333 | 0.0004537 | 0.0000046 | 600 | 0.27 | 0.0004583 | | |
| | 0.3333333 | 0.0004398 | 0.0000116 | 600 | 0.26 | 0.0004514 | | |
| | 0.3333333 | 0.0004167 | 0.0000231 | 600 | 0.24 | 0.0004398 | | |
| | 0.3333333 | 0.0003472 | 0.0000579 | 600 | 0.18 | 0.0004051 | | |
| | 0.3333333 | 0.0002315 | 0.0001157 | 600 | 0.07 | 0.0003472 | | |
| | 0.3333333 | 0.0001157 | 0.0001736 | 600 | -0.03 | 0.0002894 | | |
| | 0.3333333 | 0.0000000 | 0.0002315 | 600 | -0.13 | 0.0002315 | | |
| 1208 | 0.3333333 | 0.0007137 | 0.0000000 | 600 | 0.43 | 0.0007137 | 0.0010223 | 1 |
| | 0.3333333 | 0.0006995 | 0.0000071 | 600 | 0.42 | 0.0007066 | | |
| | 0.3333333 | 0.0006780 | 0.0000178 | 600 | 0.40 | 0.0006959 | | |
| | 0.3333333 | 0.0006424 | 0.0000357 | 600 | 0.36 | 0.0006780 | | |
| | 0.3333333 | 0.0005353 | 0.0000892 | 600 | 0.27 | 0.0006245 | | |
| | 0.3333333 | 0.0003569 | 0.0001784 | 600 | 0.11 | 0.0005353 | | |
| | 0.3333333 | 0.0001784 | 0.0002677 | 600 | -0.05 | 0.0004461 | | |
| 1617 | 0.3333333 | 0.0000000 | 0.0003569 | 600 | -0.21 | 0.0003569 | | |
| | 0.3333333 | 0.0003858 | 0.0000000 | 600 | 0.23 | 0.0003858 | 0.0005526 | 1 |
| | 0.3333333 | 0.0003781 | 0.0000039 | 600 | 0.22 | 0.0003819 | | |
| | 0.3333333 | 0.0003665 | 0.0000096 | 600 | 0.21 | 0.0003762 | | |
| | 0.3333333 | 0.0003472 | 0.0000193 | 600 | 0.20 | 0.0003665 | | |
| | 0.3333333 | 0.0002894 | 0.0000482 | 600 | 0.15 | 0.0003376 | | |
| | 0.3333333 | 0.0001929 | 0.0000965 | 600 | 0.06 | 0.0002894 | | |
| | 0.3333333 | 0.0000965 | 0.0001447 | 600 | -0.03 | 0.0002411 | | |
| | 0.3333333 | 0.0000000 | 0.0001929 | 600 | -0.11 | 0.0001929 | | |
| 0315 | 0.3333333 | 0.0003858 | 0.0000000 | 600 | 0.23 | 0.0003858 | 0.0005526 | 1 |
| | 0.3333333 | 0.0002781 | 0.0000039 | 600 | 0.22 | 0.0003819 | | |
| | 0.3333333 | 0.0002665 | 0.0000096 | 600 | 0.21 | 0.0003762 | | |
| | 0.3333333 | 0.0003472 | 0.0000193 | 600 | 0.20 | 0.0003665 | | |
| | 0.3333333 | 0.0002894 | 0.0000482 | 600 | 0.15 | 0.0003376 | | |
| | 0.3333333 | 0.0001929 | 0.0000965 | 600 | 0.06 | 0.0002894 | | |
| | 0.3333333 | 0.0000965 | 0.0001447 | 600 | -0.03 | 0.0002411 | | |
| | 0.3333333 | 0.0000000 | 0.0001929 | 600 | -0.11 | 0.0001929 | | |

COMPARISON DATA (PART TWO)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 4507 | 0.3333333 | 0.0000965 | 0.0000000 | 600 | 0.06 | 0.0000965 | 0.0001380 | 1 |
| | 0.3333333 | 0.0000945 | 0.0000010 | 600 | 0.06 | 0.0000955 | | |
| | 0.3333333 | 0.0000916 | 0.0000024 | 600 | 0.05 | 0.0000940 | | |
| | 0.3333333 | 0.0000868 | 0.0000048 | 600 | 0.05 | 0.0000916 | | |
| | 0.3333333 | 0.0000723 | 0.0000121 | 600 | 0.04 | 0.0000844 | | |
| | 0.3333333 | 0.0000482 | 0.0000241 | 600 | 0.02 | 0.0000723 | | |
| | 0.3333333 | 0.0000241 | 0.0000362 | 600 | -0.01 | 0.0000603 | | |
| | 0.3333333 | 0.0000000 | 0.0000482 | 600 | -0.03 | 0.0000482 | | |
| 1166 | 0.3333333 | 0.0012153 | 0.0000000 | 600 | 0.73 | 0.0012153 | 0.0017407 | 1 |
| | 0.3333333 | 0.0011910 | 0.0000122 | 600 | 0.71 | 0.0012031 | | |
| | 0.3333333 | 0.0011545 | 0.0000304 | 600 | 0.68 | 0.0011849 | | |
| | 0.3333333 | 0.0010938 | 0.0000608 | 600 | 0.62 | 0.0011545 | | |
| | 0.3333333 | 0.0009115 | 0.0001519 | 600 | 0.46 | 0.0010634 | | |
| | 0.3333333 | 0.0006076 | 0.0003038 | 600 | 0.19 | 0.0009115 | | |
| | 0.3333333 | 0.0003038 | 0.0004557 | 600 | -0.08 | 0.0007595 | | |
| | 0.3333333 | 0.0000000 | 0.0006076 | 600 | -0.35 | 0.0006076 | | |
| 8104 | 0.3333333 | 0.0001543 | 0.0000000 | 600 | 0.09 | 0.0001543 | 0.000221 | 1 |
| | 0.3333333 | 0.0001512 | 0.0000015 | 600 | 0.09 | 0.0001528 | | |
| | 0.3333333 | 0.0001466 | 0.0000039 | 600 | 0.09 | 0.0001505 | | |
| | 0.3333333 | 0.0001389 | 0.0000077 | 600 | 0.08 | 0.0001466 | | |
| | 0.3333333 | 0.0001157 | 0.0000193 | 600 | 0.06 | 0.0001350 | | |
| | 0.3333333 | 0.0000772 | 0.0000386 | 600 | 0.02 | 0.0001157 | | |
| | 0.3333333 | 0.0000386 | 0.0000579 | 600 | -0.01 | 0.0000965 | | |
| | 0.3333333 | 0.0000000 | 0.0000772 | 600 | -0.04 | 0.0000772 | | |
| 8106 | 0.3333333 | 0.0002122 | 0.0000000 | 600 | 0.13 | 0.0002122 | 0.0003039 | 1 |
| | 0.3333333 | 0.0002079 | 0.0000021 | 600 | 0.12 | 0.0002101 | | |
| | 0.3333333 | 0.0002016 | 0.0000053 | 600 | 0.12 | 0.0002069 | | |
| | 0.3333333 | 0.0001910 | 0.0000106 | 600 | 0.11 | 0.0002016 | | |
| | 0.3333333 | 0.0001591 | 0.0000265 | 600 | 0.08 | 0.0001857 | | |
| | 0.3333333 | 0.0001061 | 0.0000530 | 600 | 0.03 | 0.0001591 | | |
| | 0.3333333 | 0.0000530 | 0.0000796 | 600 | -0.01 | 0.0001326 | | |
| | 0.3333333 | 0.0000000 | 0.0001061 | 600 | -0.06 | 0.0001061 | | |
| 5526 | 0.3333333 | 0.0001350 | 0.0000000 | 600 | 0.08 | 0.0001350 | 0.0001934 | 1 |
| | 0.3333333 | 0.0001323 | 0.0000014 | 600 | 0.08 | 0.0001337 | | |
| | 0.3333333 | 0.0001283 | 0.0000034 | 600 | 0.08 | 0.0001317 | | |
| | 0.3333333 | 0.0001215 | 0.0000068 | 600 | 0.07 | 0.0001283 | | |
| | 0.3333333 | 0.0001013 | 0.0000169 | 600 | 0.05 | 0.0001182 | | |
| | 0.3333333 | 0.0000675 | 0.0000338 | 600 | 0.02 | 0.0001013 | | |
| | 0.3333333 | 0.0000338 | 0.0000506 | 600 | -0.01 | 0.0000844 | | |
| | 0.3333333 | 0.0000000 | 0.0000675 | 600 | -0.04 | 0.0000675 | | |
| 9552 | 0.3333333 | 0.0003858 | 0.0000000 | 600 | 0.23 | 0.0003858 | 0.0005526 | 1 |
| | 0.3333333 | 0.0003781 | 0.0000039 | 600 | 0.22 | 0.0003819 | | |
| | 0.3333333 | 0.0003665 | 0.0000096 | 600 | 0.21 | 0.0003762 | | |
| | 0.3333333 | 0.0003472 | 0.0000193 | 600 | 0.20 | 0.0003665 | | |
| | 0.3333333 | 0.0002894 | 0.0000482 | 600 | 0.15 | 0.0003376 | | |
| | 0.3333333 | 0.0001929 | 0.0000965 | 600 | 0.06 | 0.0002894 | | |
| | 0.3333333 | 0.0000965 | 0.0001447 | 600 | -0.03 | 0.0002411 | | |
| | 0.3333333 | 0.0000000 | 0.0001929 | 600 | -0.11 | 0.0001929 | | |

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